USAAVSCOM
TECHNICAL MEMORANDUM TM 85-F-3

AD

AD-A155 414

FOREIGN MILITARY SALES TERMINATION LIABILITY CURVE: APPLIED RANDOM COEFFICIENT MODEL

WILLIAM J. WAYMIRE
Operations Research Analyst

March 1985

Approved for public release;
distribution unlimited

U.S. ARMY
AVIATION
SYSTEMS COMMAND

DISCLAIMER

The view, opinions, and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy or decision, unless so designated by other documentation.

FOREIGN MILITARY SALES TERMINATION LIABILITY CURVE:

APPLIED RANDOM COEFFICIENT MODEL

William J. Waymire
Operations Research Analyst

March 1985

US Army Aviation Systems Command
Directorate for Plans and Analysis
Operational Cost Analysis Division
4300 Goodfellow Boulevard
St. Louis, MO 63120-1798

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER USAAVSCOM Technical Memorandum TM 85-F-3	2. GOVT ACCESSION NO. AD-A155414
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle) Foreign Military Sales Termination Liability Curve: Applied Random Coefficient Model	5. TYPE OF REPORT & PERIOD COVERED Interim Report
	6. PERFORMING ORG. REPORT NUMBER AMSAV-B-85-338 (TM 85-F-3)
7. AUTHOR(s) William J. Waymire	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army Aviation Systems Command Directorate for Plans and Analysis Operational Cost Analysis Division (AMSAV-BC) 4300 Goodfellow Boulevard, St. Louis, MO 63120-1798	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Same as Block 9	12. REPORT DATE March 1985
	13. NUMBER OF PAGES 66
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	15. SECURITY CLASS. (of this report) Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Random Coefficient Model, Foreign Military Sales, Termination Liability, Regression Analysis, Logistic Curve

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The Aviation Systems Command (AVSCOM) Directorate for Procurement and Production (P&P) asked the Command's Directorate for Plans and Analysis to review and update specific AVSCOM Cost Memorandums concerning Foreign Military Sales (FMS) termination liability curves. This report discusses a statistical methodology offered to update AVSCOM's FMS termination liability schedules and contrasts it with the technique employed in previous AVSCOM studies on the same subject. Applying both methods to a common data base, it is demonstrated that a linear estimation of a logistics or exponential type curve using regression analysis produces

DD FORM 1473, 1 JAN 73 EDITION OF 1 NOV 65 IS OBSOLETE UNCLASSIFIED (Cont'd)

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

20. ABSTRACT (Continued)

parameters that are not significantly different from the "equally likely" curve derived in earlier cost memorandums. It is also suggested that a Random Coefficient Model be seriously considered in future updates.

FOREWORD

The Aviation Systems Command's (AVSCOM) Directorate of Procurement and Production (P&P) asked the Command's Directorate for Plans and Analysis to review and update specific AVSCOM Cost Memorandums concerning Foreign Military Sales (FMS) termination liability curves. This report discusses the methodology used to update AVSCOM's FMS termination liability schedules and contrasts it with the technique employed in previous AVSCOM studies on this same subject. Applying both methods to a common data base, it is demonstrated that a linear estimation of a logistics or exponential type curve using regression analysis produces parameters that are not significantly different from the "equally likely" curve derived in earlier cost memorandums.

ACKNOWLEDGEMENTS

Many thanks to the following individuals for reviewing a draft of this report and providing valuable comments: Mr. Arnold Arconati, Mr. Ralph Lilge, and Mr. J.S. Sutterfield. I would also like to thank Mr. Aubrey Yawitz for providing me with both his data and experience with the FMS curve. But most of all I would like to thank Ms. Nancy Ware for all the work she put into this report.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. BACKGROUND

A. The impetus for this report originates with a 1976 study entitled, "Cost of Terminating Contracts Study (COTCOS I)." In that study, data points from five separate contracts were used to estimate a function relating percent of total contract cost to percent of contract completed. From the derived relationships, various procurement lead time schedules for Foreign Military Sales (FMS) liability payments were constructed. These schedules are utilized by the Directorate of Procurement and Production in accordance with applicable sections of the Defense Acquisition Regulations (DAR).

B. One of the expressed purposes of the COTCOS I study was to determine whether the progress payments being made by foreign military purchasers of Army aircraft were adequate to defray the cost of contract termination. It was found that the schedule of payments included in AR-37-60 did not adequately represent the progress payment requirements experienced by AVSCOM and that a schedule based upon an "equally likely" function would be more representative of AVSCOM's commodities.

C. A follow-on study, Cost of Terminating Contracts Study (COTCOS II), reported that the AVSCOM "equally likely" curve developed in the initial study was also well suited for Army aircraft shop-sets. Eight separate contracts formed the basis for COTCOS II.

Subsequent updates re-estimated the coefficients of the "equally likely" function using current contract data. A summary of the findings in these earlier studies may be found in Appendix A.

D. This memorandum presents the methodology which will be employed to update COTCOSI. Due to external difficulties with gathering new data, our initial intention to have applied the Random Coefficient Model to recent contractual information proved to be impractical. Thus in this study, we compare results from the COTCOSI methodology to that of a selected statistical model called the Random Coefficient Model using existing data found in the prior Termination Liability studies.

E. After the new data arrives, we will apply the Random Coefficient Model and include the results in a less technical format. Nonetheless, the results contained in this report are meaningful in themselves and should hold up given the forthcoming sample.

II. Discussion on Methodology

A. In this section, we address some of the issues that are involved in estimating a FMS liability curve. The topics discussed are:

1. Terminology
2. Assumptions
3. Data
4. Functional form
5. Estimation
6. Testing

These issues are important in that the user of the information provided by the estimated function can judge the validity of the results, given the usual limitations imposed upon a study of this type.

B. COTCOSI defines termination liability payments to be the amount that represents incurred costs for 90 days after payment plus the estimated amount required to "clean-up" the contract if it were terminated. DAR E-509.5 defines incurred costs as follows:

"(a) Incurred costs are costs identified through the use of accrual method of accounting and reporting. As to invoices, incurred costs include only invoices for (i) completed work to which the prime contractor has acquired title, (ii) materials delivered (to which the prime contractor has acquired title), (iii) services rendered, (iv) costs billed under cost reimbursement or time and material subcontracts for work to which the prime contractor has acquired title, and (v) invoices for progress payments to sub-contractors, which have been paid or approved for current payment in the ordinary course of business (as

as specified in the prime contract), all properly recorded on the books of the contractor and identified with the contracts. Costs incurred are exclusively costs of direct labor, direct material, and direct services identified with and necessary for the performance of the contracts, and also all properly allocable and allowable overhead (indirect) costs recorded on the books of the contractor."

The DAR goes on to say that special conditions apply for those contractors who elected to use a special transition method provided in Cost Accounting Standard (CAS) 410.

Clean up charges are addressed in DAR (7-103.21) as:

"the reasonable costs of settlement, including accounting, legal, clerical, and other expenses reasonably necessary for the preparation of settlement claims and supporting data with respect to the terminated portion of the contract and for the termination and settlement of subcontract thereunder, together with reasonable storage, transportation and other costs incurred in connection with the protection of disposition of property allocable to thi ontract."

Since part of the settlement charges are not incurred unless the contract is terminated, the data sources (DD Form 1195) used in the previous studies do not include them. Clean up costs, however, appear to be relatively small compared to the total contract dollar amount, and so need not cause too much concern. It is necessary, though, to determine as close as possible the amount of costs due to charges other than termination preparations. Some of these charges such as subcontract settlements and work in progress costs may be difficult to estimate. The Army Logistic Management Center (ALMC),

for example, agrees that a settlement should not only compensate the contractor for work completed and for preparations to terminate the contract but:

"The application of standards of business judgment as distinquised from strict accounting principles, is the heart of a settlement, The primary objective is to negotiate a settlement by agreement." (see references, ALMC).

C. This implies that overall termination costs depend in part on relative bargaining strength of the participants; the measure of which being subjective. That is, there is no straightforward way to know the outcome in advance. Given that this is true, we might ask how the clean up costs are calculated.

D. COTCOSI estimated these termination costs by assuming that reported costs (and therefore subject to termination reimbursement) lag incurrred costs according to a certain formula. The formula stated that the lag increases linearly until it reaches 90 days midway through the contract and remains constant thereafter.

E. AR 37-60 also attempts to reflect potential normal termination charges by including in the accrued expenditures those costs to be incurred during the remainder of the current quarter.

F. The most recent update to COTCOSI did not include any lag adjustments, reflecting a payment schedule rather than a termination liability schedule. A payment schedule is a sequence of payments derived from a payment curve. The payment curve represents the cumulative sum of the contractor's progress payment, the incremental portion of non-recurring costs, cost of Defense services, and administrative charges as a function of contract completion.

G. A termination liability schedule likewise is a derived listing of payments. It, however, is calculated from a termination liability curve. The termination liability curve represents the "bail out" costs incurred when the FMS customer announces termination of the FMS case; to include all accrued direct and indirect costs, and profits of prime and subcontracts not covered by contractor payments or holdback, plus any penalty contract cancellation charges for which DOD would be liable. The termination liability curve represents a function relating termination liability costs to percent of contract completed.

H. In this study the curve that is estimated is the termination liability curve showing cumulative payment costs as related to percent of contract completed. Comparisons with DOD payment curves and the AVSCOM curves estimated in previous studies are made after properly adjusting the data. These adjustments are noted where appropriate.

I. Some assumptions that pertain to the present study differ dramatically from those cited in COTCOSI. First, the curve derived in COTCOSI (and subsequent updates) is deterministic, a termination liability curve is fit assuming a function of the form $y = A(1-e^{-bx})$ and solving for each parameter using two known points; i.e., (100,100) and (.5,y) where y is the midpoint of the ordinate for the sample of contracts selected. This study, on the other hand, assumes a stochastic relationship between percent of total cost and percent of contract complete. We then fit a curve minimizing the variance about the fitted curve using the sample data. All the usual assumptions for the linear least squares estimator are made, i.e.,

1. the error terms have zero mean
2. the error terms have a common variance
3. the error terms are independent

4. the error terms are independent of the independent variable.

J. Since the independent variable ranges over all the possible values, i.e., 0 to 100 percent, the variance error is always a minimum for the true model. To see this, note that:

$$V(b) = \frac{\sigma^2}{\bar{E}(X-\bar{X})^2} .$$

Except for asse t use charges, all costs not included in progress payments request (DD Form 1195) are lump sum charges over and above total contract cost and are assumed to be time phased, in the same way as the progress payments. The charges are for Government Furnished Equipment, accessorial charges, administrative charges, incremental non-recurring costs and cost of Defense services. Asset use charges are added in at 4% of the progress payment.

K. Though inspection of the data, the functions estimated in previous studies were assumed to have the form $y = A[(- \exp - BX^2)]$. A polynomial regression was also attempted, but reportedly did not fit well. In addition, one study tried $y = A[1 - \exp - BX^3]$ on data from AR 37-60 and reported a good fit. Constraining the equation to fit through the point (100,100), the parameters were estimated by using the mean ordinate value at fifty percent completion of the contracts.

L. In this study, we transform the data assuming a logistic curve to represent the relationship between percent of contract completion and liability. By regressing the transformed dependent variable (regressand) on the independent variable, we are able to make certain statistical inferences about the data which can not be done using the technique applied in the previous studies. The form of the logistic function is

$$y = \frac{A}{1 \quad \exp(-Bo - B_1X)}$$

where A is set equal to 1.

M. This equation is intrinsically linear and capable of being estimated using Ordinary Least Squares (OLS).

Set $y^* = a + b x + u$

where $y^* = \ln \frac{Y}{1-Y}$

then $\ln \frac{y}{1-y} = a + b x + u$

$$\frac{y}{1-y} = \exp a + b x + u$$

$$y = (\exp a + b x + u) + 1$$

and

$$y = \frac{1}{\exp^{-a \; -b X \; -u} + 1}$$

N. We also apply least squares to the non-linear equations estimated in COTCOSI and its updates using the maximum likelihood function:

$$P\ (0, \sigma^2) = (2\ \sigma^2)^{\ n/2} \quad e^{-s\ (\sigma)/2\sigma^2}$$

where S (σ) is the error sum of squares. We also re-estimate the logistic equation [1.1], using non-linear least squares assuming no restriction on the parameter A.

O. Since the data is a time series across various contracts, a test was performed to determine whether any aggregation bias was introduced by pooling the data. A procedure was followed to correct this bias under the random coefficient model (RCM):

$$y_{iv} = B_{iv}\ X_{iv} + u_{iv} \qquad i = 1,\text{---},n \quad v = 1,\text{---},T$$

where i is the contract and v is the observation.

P. After the functional forms were identified, we noticed that the exponential equation in COTCOSI is a growth model with a proportional growth rate.

That is:

$$dy/dx = dA[1 - \exp - BX^2] \; /dx$$

$$= e^{-BX^2} \cdot -2BX$$

$$= -2BXe^{-BX^2}$$

Setting $BAX = K$

$$= 2K \; (A - (A + e^{-BX^2})$$

$$= 2K \; (A - Y) \text{ or } 2BAX \; (A - Y)$$

$$= 2K \; (A - Y) \text{ or } 2BAX \; (A - Y)$$

Similarly, the logistic model is also a growth model with a proportional growth rate. Setting

$$y = A/1 + \exp \; (-Bo - B_1 X)$$

we have

$$\frac{dy}{dx} = \frac{d \; A/1 \;\; + \exp(-B_o - B_{1X}).}{dx}$$

If we define $\exp \; (-B_o - B_1X) = A/y - 1$

we get

$$\frac{dy}{dx} = \frac{-AB_1 \exp \; (-B_o - B_1X)}{(1 + \exp \; (-B_o - B_1X)^2} = \frac{-AB_1 \; (A/y - 1)}{A^2/y^2}$$

$$= B_1 \; \frac{Y \; (A-Y)}{A} \; .$$

Thus, our choice of function will assume a nonconstant rate of growth regardless of the explicit form, i.e., logisitic or exponential.

Q. The technique used to estimate the function, however, is affected by the functional form of the estimate. A logistic curve, as noted above, can be estimated using OLS. If the fit is good then strong inferences can be made

about the data and tests performed to enhance those inferences. The exponential form, on the other hand, is intrinsically non-linear and one must use non-linear estimation techniques to find estimates for the parameters. Consequently tests and inferences are subject to certain restrictions that may not hold in practice. We have kept in mind, though, that the exponential equation does capture nicely the fact that the points (0,0) and (100,100) are necessarily on the curve. We recognize, however, that a non-zero intercept term may only reflect the sample size and would approach zero as the sample size increases.

R. The test which we apply are basically one of three types. The first is the usual test that indicates goodness of fit. The second type is to determine whether the parameters using COTCOSI data are significantly different over the contracts in the sample data; which, in turn, determines whether we can aggregate the data and estimate the population parameters with a single equation. Lastly, after estimating the function using the latest contract data, we will test whether or not the estimated parameters are significantly different from those estimated using COTCOSI data.

THIS PAGE INTENTIONALLY LEFT BLANK

III. APPLICATION

A. The initial phase of this study consists of a statistical analysis of COTCOSI data in order to determine the appropriate functional form of the termination liability curve. Inspection of the data appeared to have an S shape when plotted y on x. Thus a logistic curve of the form:

$$y = 1/[1 + \exp B_0 + B_1 X_0]$$

was hypothesized since this particular logistic curve can be fitted using OLS.

B. Regressing the dependent variable on the independent variable for each contract separately (assuming the logistic curve); we found good R^2 fits for each of the equations (Appendix B). However, the Durbin Watson statistics indicated that this is largely due to the autocorrelation present and not because of the linear relationship between the dependent and independent variables. Table 2 shows the results using OLS, first differencing, and quasi differencing. The differencing removes the autocorrelation in order to show the true relationship between cost and time as defined in this study. As one can see from Table 2 the results are not very promising.

C. In addition, because the available data contained both cross sectional and time series information, tests are required to determine whether pooling is appropriate.

D. Although we expect that because of autocorrelation the variance due to the regression is understated, examination of the standard error and the closeness of the estimates, themselves, is convincing in that we can not reject the hypothesis that our ML estimate is equal to the estimate in COTCOSI.

E. Since b in COTCOSI equals .000461 and the ML estimate ($\tilde{b}$) equals .000477, we want to test

$$\tilde{b} = b \text{ null hypothesis}$$

$$\tilde{b} \neq b \text{ alternate hypothesis.}$$

The ML $\tilde{b}$ standard error is .000016.

F. Using the rule of thumb that if t is greater than 2 [$t_{01\infty} = 2.6$ $t_{05,\infty} = 1.96$], we will reject the Null hypothesis when we see that the standard error exceeds

$$S^* = /b - \tilde{b}/ \div 2$$

$$= /.000477 - .000461/ \div 2$$

$$= .000008$$

which is almost 60 times less than the reported ML standard error. Similarly, we can test whether the parameter estimated for the AVSCOM curve differs significantly from the AR 37-60 parameter estimate.

Putting

$$t_{05,208} = \frac{b - 14.94798}{\sigma_b}$$

$$= \frac{8.0801 - 14.94798}{2.5469}$$

$$= 2.696$$

G. We do not accept the null hypothesis that the parameter for the AVSCOM Termination liability curve equals the AR 37-60 curve parameter.

H. The reason we do not test the AR 37-60 parameters is that the data is not a sample but an estimate presumably calculated from information on a wide spectrum of DOD contracts.

I. The hypothesis needed to pool the data is:

$$H_0 \quad B_1 = B_2 = B_3 = B_4 = B_5$$

The appropriate test is the F test where:

$$F = \frac{(RRSS - URSS)/\ K-1}{URSS/n_1 + n_2 + n_3 + n_4 + n_5 + (nK - n)}$$

and

n = number of equations

K = number of independent variables

RRSS = residual sum of squares for the entire data set

URSS = residual sum of squares of each equation summed

using the equations corrected for autocorrelation, we have

$$URSS = (.391 * 54) + (.725 * 42) + (1.08 * 25) + (.192 * 46) + (.775 * 16)] = 99.80$$

$$RRSS = 83.696 \times 197 = 16651$$

$$K = 1$$

$$n = 5$$

$$F = \frac{16651 - 99.812}{99.8/199/2} > F^*$$

We obviously reject the null hypothesis.

J. As an alternative to pooling the data under the assumption of stable parameters, we considered the hypothesis that the coefficients are random variables and used the Random Coefficient Model to estimate the population parameter b. The calculations are shown in appendix C. Noting that the equation is:

$$\text{cost} = \frac{1}{1 + \exp\,(2.62 - 8.081\ \text{Time})}$$

we have found that the coefficient b is distributed across contracts with a mean equal to -8.0807 and variance equal to 6.487. The standard error equals 2.468.

K. The data from COTCOSI was read off curves presented in the COTCOSI Cost Memorandums. Consequently, there is strong reason to suspect the presence of errors in the predicator variable. This means that the OLS estimator is biased such that $E(b) = b/\ (1 + p)$ where p is the ratio of the spread in the errors of the independent variable to the spread in the errors of the dependent variable.

L. Due to the presence of the above errors, the primary objective of this study is to prepare a methodology for data that is to be collected on contracts which are let after 1980. We expect, however, that the following findings will hold true:

1. Applying Ordinary Least Squares or the Maximum Likelihood Method to the raw data exhibits a high R^2 due to the autocorrelation present.

2. The methodology used in COTCOSI gives parameter estimates that are not significantly different from the Maximum Likelihood estimates unadjusted for autocorrelation.

3. The parameter estimates using OLS on the data adjusted for autocor-correlation are quite a bit different from the estimates on the unadjusted data.

4. The AVSCOM Termination Liability Curve is significantly different from the curve given in AR 37-60. Thus, it is recommended that a curve based upon AVSCOM contracts be employed in determining FMS liability.

5. The Random Coefficient Model using data adjusted for autocorrelation has as much explanatory power as OLS, ML, and the COTCOSI techniques even without adjustment for correlation.

THIS PAGE INTENTIONALLY LEFT BLANK

IV. RESULTS

Our conclusion, although admittedly based upon less than desirable data, are as follows:

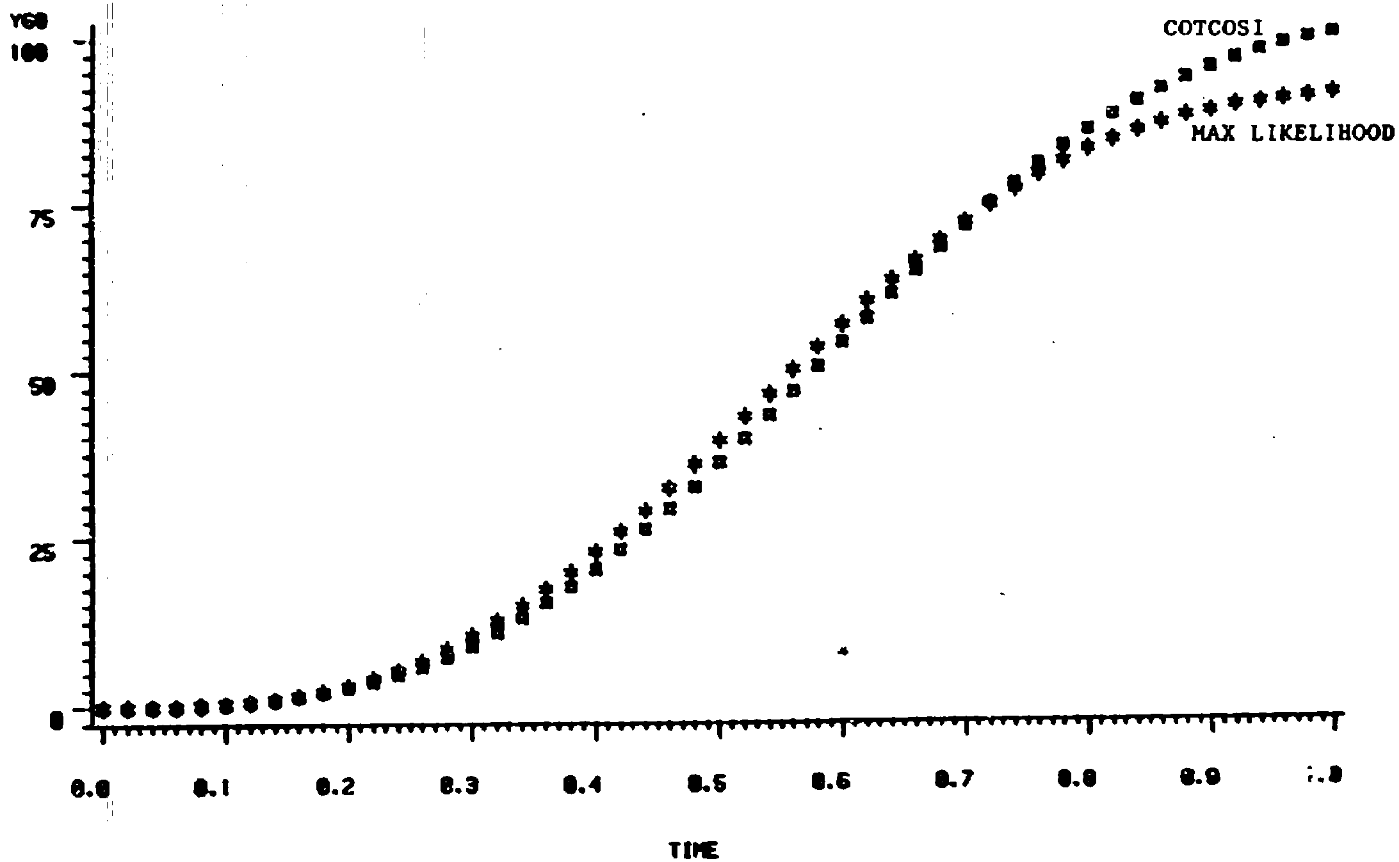
A. The COTCOSI equation as depicted in Graph 3 lies somewhat below the RCM function. This indicates that in the eyes of Foreign customers the present equation would be preferable to the estimated RCM equation. However, from AVSCOM's standpoint it would appear wise to gather new data and determine whether or not the Army should require additional funds from Foreign customers.

B. It is recommended that the present Termination Liability Curve be followed until a new sample becomes available. Then a Random Coefficient Model should be applied to the data and compared with other alternative statistical techniques as shown in this report

FIGURES

FIGURE 1

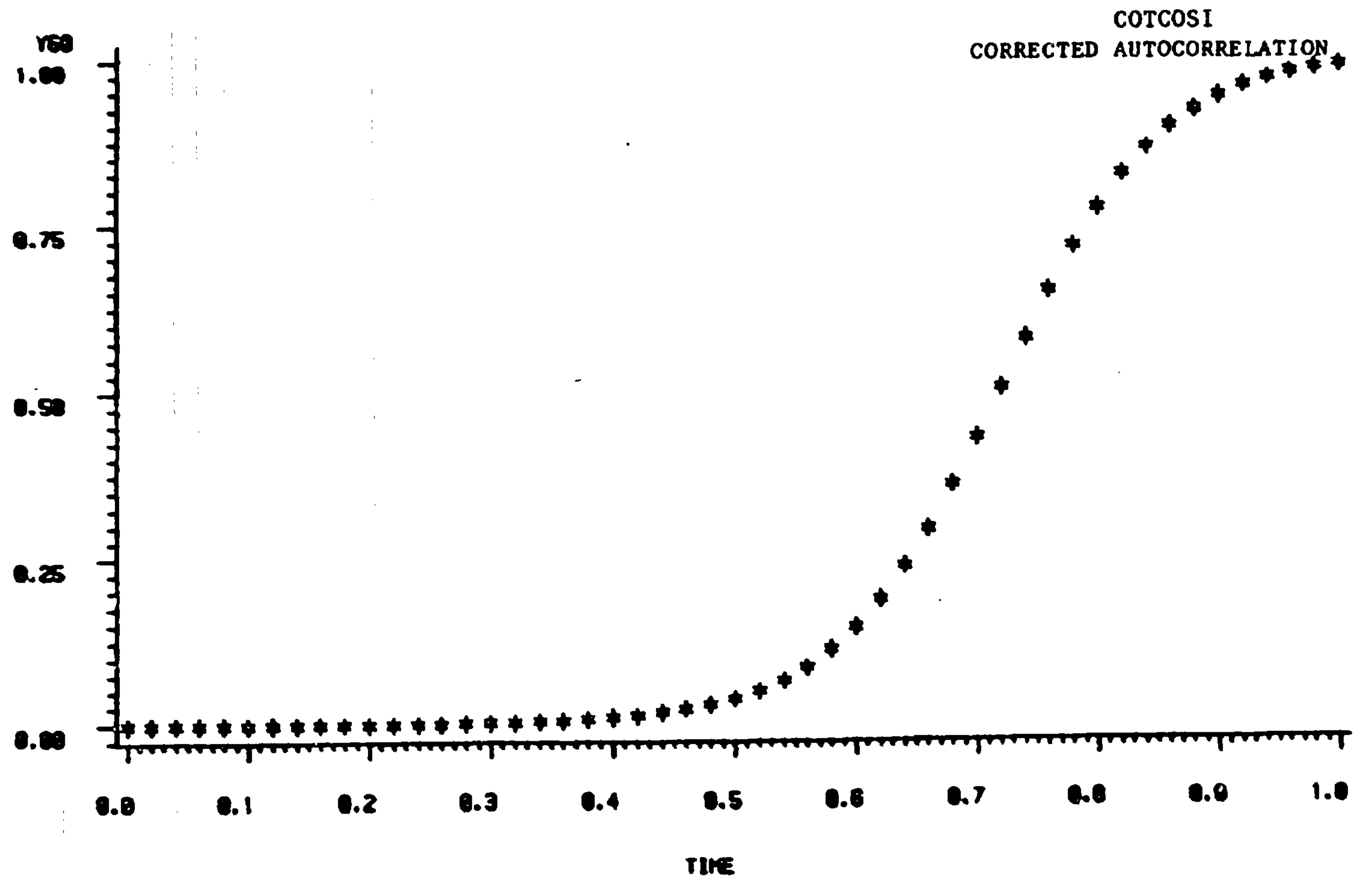
TERMINATION LIABILITY CURVES



FOREIGN MILITARY SALES

FIGURE 2

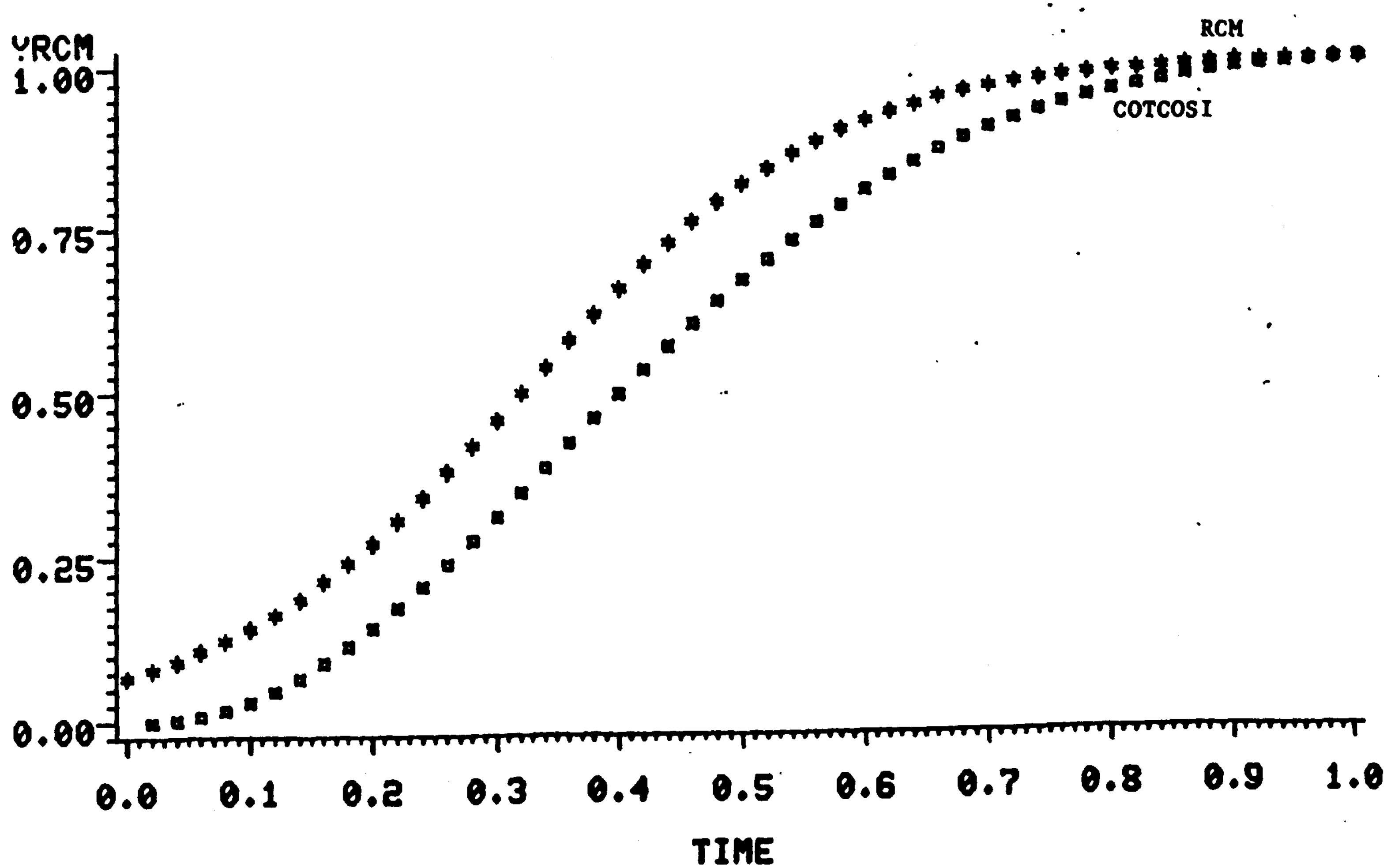
TERMINATION LIABILITY CURVES



FOREIGN MILITARY SALES

FIGURE 3

TERMINATION LIABILITY CURVES



FOREIGN MILITARY SALES

TABLES

TABLE 1

FUNCTIONAL FORMS - COTCOSI DATA

$$Y_1 = A[1 - \exp - BX_1^2]$$
$$= 99.04\ [1 - \exp - 0.0005\ X_1^2] \qquad R^2 = .88 \qquad \text{(Eq A)}$$
(3.42) (.000032)

$$Y_o = A/[1 + \exp B_o + B_1 X_o.] \qquad \text{(Eq B)}$$

$$.89/[1 + \exp 3.50 - 9.74\ X_o] \qquad R^2 = .88$$
(.028) (.200) (6.78)

$$Y_o = 1/[1 + \exp B_o + B_1\ X_o] \qquad \text{(Eq C)}$$

$$1/[1 + \exp 3.73 - 9.225\ X_o] \qquad R^2 = .88$$
(114) (.284)

$$Y_o = 1/[1 + \exp B_o + B_1\ X_o] \qquad \text{(Eq D)}$$

$$1/[1 + \exp 3.88 - 9.65\ X_o] \qquad R^2 = .86$$

$$Y_1 = A[1 - \exp BX_1^3] \qquad \text{(Eq E)}$$
$$83.06\ [1 - \exp .00002\ X_1^3] \qquad R^2 = .87$$
(1.89) (.000001)

$$Y_o = 1/[1 + \exp B_o + B_1 X_o]$$
$$1/[1 + \exp 3.19 - 8.14\ X_o] \qquad R^2 = .87 \qquad \text{(Eq F)}$$
(.144) (.359)

$$Y_1 = A[1 - \exp BX_1]$$
Not Significant (Eq G)

$$Y_o = 1/[1 + \exp B_o + B_1 X_o] \qquad \text{(Eq H)}$$
$$1/[1 + \exp 2.616 - 8.082\ X_o] \qquad R^2 = .88$$

Equations A, B, E, F, and G were estimated using non-linear regression

Equation C is a linear transformation of logistic curve

Equation D is adjusted using random coefficient model of Equation C.

Equation H is the Random coefficient model adjusted for autocorrelation.

$X_1 = 100 * X_0$

* Values in parenthesis are standard errors.

TABLE 2

CORRECTING FOR AUTOCORRELATION

CONTRACT	COEFFICIENTS		R^2	$\hat{\sigma}^2$	DW
	CONSTANT	B			
#1 OLS	-4.401	9.470	.99	139.4	.57
#1 first differenced	-0.015	11.687	.60	.97	2.30
#1 quasi differenced	-0.115	10.413	.51	.81	2.19
#2 OLS	-4.183	12.889	.97	171.8	.226
#2 first differenced	0.068	8.125	.08	.81	1.31
#2 quasi differenced	0.082	6.163	.04	.02	1.29
#3 OLS	-4.544	11.900	.99	128.8	.75
#3 first differenced	0.069	9.768	.13	1.47	2.03
#3 quasi differenced	-1.82	11.924	.94	19.4	1.58
#4 OLS	-2.952	7.500	.98	49.72	.26
#4 first differenced	0.052	3.268	.12	.211	1.55
#4 quasi differenced	-0.163	6.195	.67	.58	2.08
#5 OLS	-3.112	6.460	.96	29.55	1.10
#5 first differenced	.069	4.517	.08	1.23	2.73
#5 quasi differenced	-1.617	5.837	.89	7.27	2.33

TABLE 3

LOGISTIC EQUATIONS BY INDIVIDUAL CONTRACT*,**

Eq 1	y_1	=	-4.79	+	10.41	X
			(1.25)		(1.36)	
Eq 2	y_2	=	20.6	+	6.16	X
			(209.5)		(4.4)	
Eq 3	y_3	=	-4.516	+	11.92	X
			(.06)		(.58)	
Eq 4	y_4	=	-2.18	+	6.19	X
			(.12)		(.64)	
Eq 5	y_5	=	-3.43	+	5.84	X
			(.078)		(.50)	

FOOTNOTES:

* Numbers in parentheses are standard errors

Equation 2 is not significant

** See Appendix B

REFERENCES

AR 12-8 Foreign Military Sales Operations/Procedures, 1 February 1981.

AR 37-60 Pricing for Materiel and Services, 15 March 1983.

Berenson, Mark L. et al, Intermediate Statistical Methods, and Applications-A Complete Package Approach, (Englewood Cliffs, N.J.; Prentice-Hall Inc. 1983).

Draper, N.R. and H. Smith, Applied Regression Analysis, (New York: John Wiley & Sons, Inc. 1981).

Griliches Z and V Rengstad, "Error-in-the-Variables Bias in Nonlinear Contexts," Econometrics, Vol. 38, March 1970.

Maddala G.S., Econometrics, (McGraw-Hill Book Co., 1977).

Kelejian, H. H. and W. Oates, Introduction to Econometrics Principles and Applications, (New York: Harper and Row, Publishers, 1974).

Sutterfield, J.S., "Cost of Terminating Contracts Study (COTCOSI)," USAAVSCOM TM 76-44, November 1976).

Sutterfield, J.S., "Cost of Terminating Contracts Study (COTCOSII)," USAAVSCOM TR-77-25, April 1977.

Swamy P. A.V.B., Statistical Inference in Random Coefficient Regression Models, (New York, NY: Springer Verlag, 1971).

US Army Logistics Management Center, Lesson Book for Management of Defense Acquisition Contracts Course (Correspondence Contracts 11). Fort Lee, VA pp 1103-29.

Yawitz, Aubrey and C.E. Lasswell, "Costs of Terminating Army Aircraft Contracts Update," Cost Memorandum 81-6, (USATSARCOM, February 1981).

Yawitz, Aubrey, "AR 37-60 Termination Liability Costs," Cost Memorandum 83-28, USATSARCOM, August 1983).

Yawitz, Aubrey, "Costs of Terminating Army Aircraft Contracts Update II," Cost Memorandum 84-2, (USATSARCOM, October 1983).

APPENDIX A

Summary of Previous Findings

Equations		Tech Report #
Eq^1	$Y = 101\ [1 - \exp -0.00046152\ X^2]$	COTCOS I
Eq^2	$Y = 103\ [1 - \exp -0.00035362\ X^2]$	COTCOS II
Eq^3	$Y = 109.96\ [1 - \exp -0.00024015\ X^2]$	CM 81-6
Eq^4	$Y = 103.08\ [1 - \exp -0.00035100\ X^2]$	CM 84-2

FOOTNOTES:

Eq^1 represents Aviation end items and includes Lag.

Eq^2 represents shop-sets and includes Lag.

Eq^3 represents update of Eq^1 using recent contract data.

Eq^4 represents update of Eq^3 but does not have a lag adjustment.

APPENDIX B

Regression Output with Autocorrelation Removed

DEP VARIABLE: DWY1

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	1	138.305	138.305	6759.782	0.0001
ERROR	55	1.125299	0.020460		
C TOTAL	56	139.430			

ROOT MSE	0.143038	R-SQUARE	0.9919
DEP MEAN	-0.491852	ADJ R-SQ	0.9918
C.V.	-29.0816		

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|
INTERCEP	1	-4.401469	0.051187	-85.988	0.0001
DWX1	1	9.469604	0.115177	82.218	0.0001

OBS	ACTUAL	PREDICT VALUE	STD ERR PREDICT	LOWER95% PREDICT	UPPER95% PREDICT	RESIDUAL	STD ERR RESIDUAL	STUDENT RESIDUAL	-2-1-0 1 2	COOK'S D
1	.	-4.401	0.051187	-4.706	-4.097	.	.	.		.
2	-4.595	-3.975	0.046412	-4.277	-3.674	-.619783	0.135299	-4.581	******	1.235
3	-3.892	-3.549	0.041734	-3.848	-3.251	-.342616	0.136815	-2.504	*****	0.292
4	-3.317	-3.312	0.039190	-3.610	-3.015	-.004316	0.137565	-0.031		0.000
5	-3.055	-3.028	0.036204	-3.324	-2.733	-.026673	0.138381	-0.193		0.001
6	-2.752	-2.744	0.033309	-3.039	-2.450	-.007247	0.139106	-0.052		0.000
7	-2.442	-2.508	0.030984	-2.801	-2.214	0.065201	0.139642	0.467		0.005
8	-2.376	-2.318	0.029195	-2.611	-2.026	-.059117	0.140027	-0.415		0.004
9	-2.314	-2.271	0.028760	-2.563	-1.978	-.042827	0.140117	-0.306		0.002
10	-2.197	-2.176	0.027903	-2.468	-1.884	-.021113	0.140290	-0.150		0.000
11	-2.143	-2.119	0.027400	-2.411	-1.827	-.023569	0.140390	-0.168		0.001
12	-2.091	-2.034	0.026661	-2.326	-1.742	-.056673	0.140532	-0.403		0.003
13	-2.091	-1.987	0.026259	-2.278	-1.695	-.104021	0.140607	-0.740	*	0.010
14	-1.774	-1.892	0.025475	-2.183	-1.601	0.117656	0.140752	0.836	*	0.011
15	-1.735	-1.845	0.025094	-2.136	-1.554	0.110075	0.140820	0.782	*	0.010
16	-1.666	-1.750	0.024354	-2.041	-1.459	0.084292	0.140950	0.598	*	0.005
17	-1.621	-1.703	0.023996	-1.993	-1.412	0.081146	0.141011	0.575	*	0.005
18	-1.516	-1.655	0.023647	-1.946	-1.365	0.138936	0.141070	0.985	*	0.014
19	-1.386	-1.513	0.022656	-1.803	-1.223	0.126945	0.141233	0.899	*	0.010
20	-1.266	-1.371	0.021756	-1.661	-1.081	0.105529	0.141374	0.746	*	0.007
21	-1.153	-1.276	0.021214	-1.566	-.986709	0.123820	0.141457	0.875	*	0.009
22	-1.072	-1.163	0.020629	-1.452	-.873244	0.090744	0.141543	0.641	*	0.004
23	-.919793	-.992412	0.019900	-1.282	-.702996	0.072618	0.141647	0.513	*	0.003
24	-.753772	-.897715	0.019578	-1.187	-.608388	0.143944	0.141692	1.016	**	0.010
25	-.708185	-.850367	0.019441	-1.140	-.561077	0.142182	0.141711	1.003	**	0.009
26	-.597133	-.708323	0.019128	-.997530	-.419117	0.111191	0.141754	0.784	*	0.006
27	-.553728	-.660975	0.019057	-.950163	-.371787	0.107240	0.141763	0.757	*	0.005
28	-.447312	-.566279	0.018968	-.855444	-.277115	0.118967	0.141775	0.639	*	0.006
29	-.405465	-.518931	0.018949	-.808091	-.229772	0.113466	0.141778	0.800	*	0.006
30	-.241162	-.424235	[illegible]	-.713399	-.135072	0.183073	0.141776	1.291	**	0.015
31	-.200671	-.329539	0.019048	-.618725	-.040354	0.128869	0.141764	0.909	*	0.007
32	-.160343	-.282191	0.019117	-.571395	0.007012	0.121849	0.141755	0.860	*	0.007

OBS	ACTUAL	PREDICT VALUE	STD ERR PREDICT	LOWER95% PREDICT	UPPER95% PREDICT	RESIDUAL	STD ERR RESIDUAL	STUDENT RESIDUAL	-2-1-0 1 2	COOK'S D
33	-.040005	-.234843	0.019202	-.524070	0.054383	0.194838	0.141744	1.375	|**	0.017
34	0.040005	-.045451	0.019709	-.334814	0.243912	0.085456	0.141674	0.603	|*	0.004
35	0.120144	0.049245	0.020056	-.240214	0.338704	0.070899	0.141625	0.501	|*	0.003
36	0.200671	0.143941	0.020463	-.145633	0.433514	0.056730	0.141567	0.401	|	0.002
37	0.241162	0.191289	0.020688	-.098349	0.480927	0.049873	0.141534	0.352	|	0.001
38	0.322773	0.238637	0.020926	-.051069	0.528343	0.084136	0.141499	0.595	|*	0.004
39	0.363965	0.380681	0.021716	0.090741	0.670621	-.016716	0.141380	-0.118	|	0.000
40	0.489548	0.428029	0.022003	0.138003	0.718056	0.061519	0.141336	0.435	|	0.002
41	0.575364	0.522725	0.022610	0.232511	0.812939	0.052639	0.141240	0.373	|	0.002
42	0.619039	0.617421	0.023259	0.327001	0.907841	0.001618	0.141135	0.011	|	0.000
43	0.663294	0.664769	0.023598	0.374240	0.955299	-.001475	0.141076	-0.010	|	0.000
44	0.663294	0.806813	0.024667	0.515927	1.098	-.143519	0.140895	-1.019	**|	0.016
45	0.753772	0.854161	0.025039	0.563147	1.145	-.100389	0.140830	-0.713	*|	0.008
46	0.800119	0.996205	0.026201	0.704781	1.288	-.196086	0.140618	-1.394	**|	0.034
47	0.847298	1.091	0.027010	0.799181	1.383	-.243603	0.140465	-1.734	***|	0.056
48	0.994623	1.138	0.027423	0.846374	1.430	-.143627	0.140385	-1.023	**|	0.020
49	1.099	1.280	0.028697	0.987926	1.573	-.181681	0.140130	-1.297	**|	0.035
50	1.208	1.375	0.029572	1.082	1.668	-.166678	0.139948	-1.191	**|	0.032
51	1.355	1.470	0.030465	1.177	1.763	-.114353	0.139756	-0.818	*|	0.016
52	1.450	1.517	0.030918	1.224	1.810	-.067023	0.139657	-0.480	|	0.006
53	1.483	1.564	0.031376	1.271	1.858	-.081549	0.139555	-0.584	*|	0.009
54	1.586	1.659	0.032301	1.365	1.953	-.073450	0.139344	-0.527	*|	0.007
55	1.658	1.659	0.032301	1.365	1.953	-8.5E-04	0.139344	-0.006	|	0.000
56	1.782	1.754	0.033241	1.459	2.048	0.028684	0.139122	0.206	|	0.001
57	1.815	1.943	0.035158	1.648	2.238	-.127876	0.138650	-0.922	*|	0.027
58	2.314	2.322	0.039118	2.025	2.619	-.008315	0.137585	-0.060	|	0.000
59	.	5.068	0.070229	4.749	5.387	.	.	.		.

SUM OF RESIDUALS -3.62085E-13
SUM OF SQUARED RESIDUALS 1.125299

DURBIN-WATSON D 0.566
1ST ORDER AUTOCORRELATION 0.976

APPENDIX B (Continued)
Variable DWY2

DEP VARIABLE: DWY2

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	1	167.479	167.479	1696.378	0.0001
ERROR	44	4.344012	0.098728		
C TOTAL	45	171.823			

ROOT MSE	0.314209	R-SQUARE	0.9747
DEP MEAN	-0.061337	ADJ R-SQ	0.9741
C.V.	-512.25		

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|
INTERCEP	1	-4.183229	0.110280	-37.933	0.0001
DWX2	1	12.888788	0.312933	41.187	0.0001

OBS	ACTUAL	PREDICT VALUE	STD ERR PREDICT	LOWER95% PREDICT	UPPER95% PREDICT	RESIDUAL	STD ERR RESIDUAL	STUDENT RESIDUAL	-2-1-0 1 2	COOK'S D
1	.	-4.183	0.110280	-4.854	-3.512	.	.	.		.
2	-4.595	-3.668	0.099861	-4.332	-3.004	-.927442	0.298185	-3.110	******	0.534
3	-4.411	-3.410	0.093574	-4.071	-2.749	-1.001	0.299952	-3.337	******	0.542
4	-3.892	-3.281	0.090869	-3.940	-2.622	-.610006	0.300783	-2.031	****	0.188
5	-3.178	-3.152	0.088191	-3.810	-2.494	-.025928	0.301579	-0.086		0.000
6	-2.944	-3.023	0.085544	-3.680	-2.367	0.078799	0.302348	0.261		0.003
7	-2.752	-2.830	0.081637	-3.484	-2.176	0.078371	0.303419	0.258		0.002
8	-2.587	-2.637	0.077818	-3.289	-1.984	0.049885	0.304421	0.164		0.001
9	-2.415	-2.443	0.074099	-3.094	-1.793	0.027765	0.305347	0.091		0.000
10	-2.197	-2.185	0.069325	-2.834	-1.537	-.011758	0.306466	-0.038		0.000
11	-1.901	-1.992	0.065908	-2.639	-1.345	0.091176	0.307219	0.297		0.002
12	-1.586	-1.799	0.062656	-2.445	-1.153	0.213176	0.307899	0.692	*	0.010
13	-1.386	-1.605	0.059597	-2.250	-.960936	0.219177	0.308506	0.710	*	0.009
14	-1.325	-1.541	0.058625	-2.185	-.896855	0.216102	0.308692	0.700	*	0.009
15	-1.099	-1.348	0.055872	-1.991	-.704517	0.249083	0.309202	0.806	*	0.011
16	-.847298	-1.090	0.052630	-1.732	-.447853	0.242622	0.309770	0.783	*	0.009
17	-.532217	-.857922	0.050203	-1.499	-.216645	0.325705	0.310173	1.050	**	0.014
18	-.281851	-.703256	0.048879	-1.344	-.062395	0.421405	0.310384	1.358	**	0.023
19	-.200671	-.574368	0.047973	-1.215	0.066215	0.373698	0.310526	1.203	**	0.017
20	0	-.445481	0.047257	-1.086	0.194886	0.445481	0.310635	1.434	**	0.024
21	0.044007	-.381637	0.046973	-1.021	0.259245	0.425644	0.310678	1.368	**	0.021
22	0.060018	-.123261	0.046352	-.763359	0.516837	0.183279	0.310772	0.590	*	0.004
23	0.363965	0.134515	0.046571	-.505648	0.774678	0.229450	0.310739	0.738	*	0.006
24	0.384674	0.198959	0.046757	-.441259	0.839177	0.185716	0.310711	0.598	*	0.004
25	0.532217	0.263403	0.046994	-.376885	0.903691	0.268814	0.310675	0.865	*	0.009
26	0.708185	0.521179	0.048438	-.119547	1.162	0.187007	0.310453	0.602	*	0.004
27	0.800119	0.585622	0.048918	-.055251	1.226	0.214497	0.310378	0.691	*	0.006
28	0.847298	0.714510	0.050011	0.073295	1.356	0.132788	0.310204	0.428		0.002
29	0.895384	0.778954	0.050621	0.137544	1.420	0.116430	0.310105	0.375		0.002
30	0.994623	0.843398	0.051272	0.201778	1.485	0.151224	0.309996	0.488		.003
31	1.046	0.972286	[illegible]	0.330200	1.614	0.073682	0.309760	0.238		.001
32	1.153	1.037	0.053451	0.394388	1.679	0.115949	0.309630	0.374		.002

OBS	ACTUAL	PREDICT VALUE	STD ERR PREDICT	LOWER95% PREDICT	UPPER95% PREDICT	RESIDUAL	STD ERR RESIDUAL	STUDENT RESIDUAL	-2-1-0 1 2	COOK'S D
33	1.208	1.127	0.054577	0.484225	1.770	0.081360	0.309433	0.263		0.001
34	1.225	1.295	0.056832	0.650986	1.938	-.069177	0.309027	-0.224		0.001
35	1.266	1.372	0.057940	0.727917	2.016	-.106172	0.308821	-0.344		0.002
36	1.325	1.488	0.059674	0.843274	2.132	-.162912	0.308491	-0.528	*	0.005
37	1.386	1.617	0.061694	0.971309	2.262	-.230431	0.308093	-0.748	*	0.011
38	1.516	1.746	0.063804	1.099	2.392	-.229266	0.307663	-0.745	*	0.012
39	1.586	1.939	0.067118	1.291	2.586	-.353318	0.306957	-1.151	**	0.032
40	1.901	2.003	0.068259	1.355	2.651	-.102430	0.306705	-0.334		0.003
41	1.992	2.132	0.070589	1.483	2.781	-.139847	0.306178	-0.457		0.006
42	2.091	2.261	0.072979	1.611	2.911	-.170424	0.305617	-0.558	*	0.009
43	2.197	2.390	0.075423	1.739	3.041	-.192828	0.305023	-0.632	*	0.012
44	2.314	2.519	0.077917	1.867	3.171	-.205306	0.304395	-0.674	*	0.015
45	2.442	2.648	0.080454	1.994	3.302	-.205481	0.303735	-0.677	*	0.016
46	2.442	2.777	0.083032	2.122	3.432	-.334369	0.303040	-1.103	**	0.046
47	2.587	2.906	0.085647	2.249	3.562	-.318915	0.302311	-1.055	**	0.045
48	.	8.706	0.217839	7.935	9.476	.	.	.		.

SUM OF RESIDUALS -1.26565E-13
SUM OF SQUARED RESIDUALS 4.344012

DURBIN-WATSON D 0.226
1ST ORDER AUTOCORRELATION 0.996

APPENDIX B (Continued)

Variable DWY3

DEP VARIABLE: DWY3

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	1	127.043	127.043	1860.133	0.0001
ERROR	26	1.775739	0.068298		
C TOTAL	27	128.818			

ROOT MSE	0.261338	R-SQUARE	0.9862
DEP MEAN	-0.699889	ADJ R-SQ	0.9857
C.V.	-37.3399		

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|
INTERCEP	1	-4.543754	0.101894	-44.593	0.0001
DWX3	1	11.908510	0.275927	43.129	0.0001

OBS	ACTUAL	PREDICT VALUE	STD ERR PREDICT	LOWER95% PREDICT	UPPER95% PREDICT	RESIDUAL	STD ERR RESIDUAL	STUDENT RESIDUAL	-2-1-0 1 2	COOK'S D
1	.	-4.544	0.101894	-5.120	-3.967	.	.	.		.
2	-4.595	-4.425	0.099489	-5.000	-3.850	-.170371	0.241660	-0.705	*|	0.042
3	-3.892	-4.068	0.092395	-4.638	-3.498	0.175913	0.244460	0.720	|*	0.037
4	-3.892	-3.830	0.087781	-4.396	-3.263	-.062097	0.246155	-0.252	|	0.004
5	-3.476	-3.413	0.079981	-3.975	-2.851	-.062893	0.248798	-0.253	|	0.003
6	-3.178	-3.116	0.074677	-3.674	-2.557	-.062361	0.250442	-0.249	|	0.003
7	-2.944	-2.878	0.070632	-3.434	-2.321	-.066757	0.251612	-0.265	|	0.003
8	-2.769	-2.521	0.064973	-3.074	-1.967	-.248739	0.253133	-0.983	*|	0.032
9	-2.587	-2.390	0.063043	-2.942	-1.837	-.196928	0.253620	-0.776	*|	0.019
10	-2.314	-2.223	0.060717	-2.775	-1.672	-.090481	0.254187	-0.356	|	0.004
11	-2.091	-1.926	0.056982	-2.475	-1.376	-.165100	0.255050	-0.647	*|	0.010
12	-1.516	-1.509	0.052832	-2.057	-.961073	-.007224	0.255942	-0.028	|	0.000
13	-1.153	-1.271	0.051133	-1.818	-.723744	0.118434	0.256287	0.462	|	0.004
14	-.753772	-.973601	0.049794	-1.520	-.426753	0.219829	0.256551	0.857	|*	0.014
15	-.426343	-.830795	0.049481	-1.378	-.284067	0.404452	0.256611	1.576	|***	0.046
16	-.200671	-.604685	0.049438	-1.151	-.057974	0.404014	0.256620	1.574	|***	0.046
17	0	-.259570	0.050432	-.806665	0.287525	0.259570	0.256426	1.012	|**	0.020
18	0.281851	-.021560	0.051832	-.569207	0.526087	0.303411	0.256147	1.185	|**	0.029
19	0.405465	0.156948	0.053234	-.391268	0.705163	0.248517	0.255859	0.971	|*	0.020
20	0.489548	0.394958	0.055530	-.154219	0.944135	0.094590	0.255370	0.370	|	0.003
21	0.708185	0.751973	0.059770	0.200919	1.303	-.043788	0.254412	-0.172	|	0.001
22	0.994623	1.168	0.065695	0.614594	1.722	-.173868	0.252946	-0.687	*|	0.016
23	1.208	1.228	0.066613	0.673634	1.782	-.019682	0.252706	-0.078	|	0.000
24	1.266	1.287	0.067547	0.732659	1.842	-.021830	0.252458	-0.086	|	0.000
25	1.325	1.645	0.073443	1.087	2.203	-.319586	0.250806	-1.274	**|	0.070
26	1.516	2.002	0.079765	1.440	2.563	-.485179	0.248868	-1.950	***|	0.195
27	1.735	2.359	0.086417	1.793	2.924	-.523941	0.246637	-2.530	*****|	0.393
28	2.944	2.716	[illegible]	2.145	3.286	0.228882	0.244105	0.938	|*	0.064
29	3.317	2.954	[illegible]	2.380	3.527	0.363213	0.242245	1.499	|**	0.184
30	.	7.357	[illegible]	6.68[illegible]	8.025	.	.	.		.

SUM OF RESIDUALS -6.92371E-14
SUM OF SQUARED RESIDUALS 1.775739

DURBIN-WATSON D	0.747
1ST ORDER AUTOCORRELATION	0.597

APPENDIX B (Continued)

Variable DWY4

DEP VARIABLE: DWY4

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	1	48.730793	48.730793	2323.066	0.0001
ERROR	47	0.985916	0.020977		
C TOTAL	48	49.716708			

ROOT MSE	0.144834	R-SQUARE	0.9802
DEP MEAN	-0.109838	ADJ R-SQ	0.9797
C.V.	-131.861		

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|
INTERCEP	1	-2.951696	0.062487	-47.237	0.0001
DWX4	1	7.499920	0.155606	48.198	0.0001

OBS	ACTUAL	PREDICT VALUE	STD ERR PREDICT	LOWER95% PREDICT	UPPER95% PREDICT	RESIDUAL	STD ERR RESIDUAL	STUDENT RESIDUAL	-2-1-0 1 2	COOK'S D
1	.	-2.952	0.062487	-3.269	-2.634	.	.	.		.
2	-1.992	-1.677	0.038535	-1.978	-1.375	-.315721	0.139614	-2.261	| ****| |	0.195
3	-1.901	-1.542	0.036203	-1.842	-1.241	-.359248	0.140236	-2.562	| *****| |	0.219
4	-1.815	-1.527	0.035948	-1.827	-1.227	-.288579	0.140302	-2.057	| ****| |	0.139
5	-1.658	-1.452	0.034687	-1.751	-1.152	-.206516	0.140619	-1.469	| **| |	0.066
6	-1.450	-1.414	0.034066	-1.714	-1.115	-.035798	0.140771	-0.254	| | |	0.002
7	-1.386	-1.339	0.032843	-1.638	-1.040	-.047082	0.141061	-0.334	| | |	0.003
8	-1.325	-1.302	0.032243	-1.600	-1.003	-.023212	0.141200	-0.164	| | |	0.001
9	-1.266	-1.227	0.031066	-1.525	-.928719	-.038952	0.141463	-0.275	| | |	0.002
10	-1.099	-1.152	0.029923	-1.449	-.854194	0.053102	0.141709	0.375	| | |	0.003
11	-1.046	-1.077	0.028819	-1.374	-.779636	0.030747	0.141938	0.217	| | |	0.001
12	-.944462	-1.039	0.028283	-1.336	-.742345	0.094754	0.142046	0.667	| |* |	0.007
13	-.895384	-.964217	0.027246	-1.261	-.667738	0.068833	0.142248	0.484	| | |	0.004
14	-.753772	-.926717	0.026746	-1.223	-.630423	0.172945	0.142343	1.215	| |** |	0.026
15	-.663294	-.866718	0.025975	-1.163	-.570701	0.203424	0.142486	1.428	| |** |	0.034
16	-.619039	-.851718	0.025788	-1.148	-.555768	0.232679	0.142520	1.633	| |*** |	0.044
17	-.532217	-.776719	0.024891	-1.072	-.481080	0.244502	0.142679	1.714	| |*** |	0.045
18	-.489548	-.739219	0.024467	-1.035	-.443723	0.249671	0.142753	1.749	| |*** |	0.045
19	-.447312	-.664220	0.023673	-.959454	-.368986	0.216908	0.142886	1.518	| |*** |	0.032
20	-.405465	-.626720	0.023305	-.921836	-.331605	0.221255	0.142947	1.548	| |*** |	0.032
21	-.322773	-.476722	0.022046	-.771446	-.181998	0.153949	0.143146	1.075	| |** |	0.014
22	-.281851	-.401723	0.021559	-.696301	-.107145	0.119872	0.143221	0.837	| |* |	0.008
23	-.241162	-.326724	0.021174	-.621189	-.032258	0.085562	0.143278	0.597	| |* |	0.004
24	-.200671	-.251724	0.020899	-.546110	0.042661	0.051054	0.143318	0.356	| | |	0.001
25	-.160343	-.176725	0.020737	-.471064	0.117614	0.016383	0.143342	0.114	| | |	0.000
26	-.140229	-.139226	0.020700	-.433554	0.155103	-.001004	0.143347	-0.007	| | |	0.000
27	-.124159	-.116726	0.020691	-.411052	0.177600	-.007433	0.143349	-0.052	| | |	0.000
28	-.080043	-.101726	0.020691	-.396052	0.192600	0.021683	0.143349	0.151	| | |	0.000
29	-.040605	-.026727	[illegible]	-.321073	0.267620	-.013279	0.143338	-0.093	| | |	0.000
30	0.040005	0.010773	[illegible]	-.283596	0.305142	0.029233	0.143327	0.204	| | |	0.000
31	0.080043	0.085772	[illegible]	-.208667	0.380211	-.005729	0.143291	-0.040	| | |	0.000
32	0.120144	0.123272	0.021248	-.171215	0.417758	-.003127	0.143267	-0.022	| | |	0.000

OBS	ACTUAL	PREDICT VALUE	STD ERR PREDICT	LOWER95% PREDICT	UPPER95% PREDICT	RESIDUAL	STD ERR RESIDUAL	STUDENT RESIDUAL	-2-1-0 1 2	COOK'S D
33	0.160343	0.198271	0.021656	-.096336	0.492878	-.037928	0.143206	-0.265		0.001
34	0.200671	0.258270	0.022055	-.036456	0.552997	-.057599	0.143145	-0.402		0.002
35	0.241162	0.310770	0.022456	0.015921	0.605619	-.069608	0.143083	-0.486		0.003
36	0.281851	0.385769	0.023105	0.090717	0.680821	-.103918	0.142979	-0.727	*	0.007
37	0.363965	0.498268	0.024234	0.202849	0.793686	-.134302	0.142792	-0.941	*	0.013
38	0.447312	0.535767	0.024648	0.240210	0.831324	-.088455	0.142721	-0.620	*	0.006
39	0.532217	0.648266	0.025990	0.352244	0.944288	-.116049	0.142483	-0.814	*	0.011
40	0.663294	0.760765	0.027466	0.464204	1.057	-.097471	0.142206	-0.685	*	0.009
41	0.753772	0.873264	0.029054	0.576091	1.170	-.119492	0.141890	-0.842	*	0.015
42	0.758371	0.910763	0.029605	0.613371	1.208	-.152392	0.141776	-1.075	**	0.025
43	0.847298	1.023	0.031317	0.725161	1.321	-.175964	0.141408	-1.244	**	0.038
44	0.994623	1.136	0.033186	0.836878	1.435	-.141138	0.141000	-1.001	**	0.028
45	1.325	1.211	0.034334	0.911317	1.510	0.114165	0.140706	0.811	*	0.020
46	1.516	1.436	0.038163	1.134	1.737	0.080598	0.139716	0.577	*	0.012
47	1.658	1.548	0.040144	1.246	1.851	0.109972	0.139159	0.790	*	0.026
48	1.815	1.698	0.042841	1.394	2.002	0.117035	0.138353	0.846	*	0.034
49	1.901	1.998	0.048385	1.691	2.305	-.097293	0.136513	-0.713	*	0.032
50	2.197	2.148	0.051216	1.839	2.457	0.048975	0.135477	0.361		0.009
51	.	4.548	0.098834	4.195	4.901	.	.	.		.

SUM OF RESIDUALS -1.71238E-13
SUM OF SQUARED RESIDUALS 0.9859156

DURBIN-WATSON D 0.261
1ST ORDER AUTOCORRELATION 0.925

FMS PAYMENT SCHEDULE FUNCTION
APPENDIX B (Continued)
Variable DWY5

DEP VARIABLE: DWY5

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	1	28.349257	28.349257	400.588	0.0001
ERROR	17	1.203074	0.070769		
C TOTAL	18	29.552332			

ROOT MSE	0.266025	R-SQUARE	0.9593
DEP MEAN	-0.694281	ADJ R-SQ	0.9569
C.V.	-38.3166		

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|
INTERCEP	1	-3.112785	0.135374	-22.994	0.0001
DWY5	1	6.460224	0.322774	20.015	0.0001

OBS	ACTUAL	PREDICT VALUE	STD ERR PREDICT	LOWER95% PREDICT	UPPER95% PREDICT	RESIDUAL	STD ERR RESIDUAL	STUDENT RESIDUAL	-2-1-0 1 2	COOK'S D
1	.	-3.113	0.135374	-3.743	-2.483	.	.	.		.
2	-3.178	-2.790	0.121187	-3.487	-2.173	-.388280	0.236818	-1.640	| ***| |	0.352
3	-2.752	-2.467	0.107552	-3.072	-1.861	-.284773	0.243314	-1.170	| **| |	0.134
4	-2.197	-2.305	0.101011	-2.906	-1.705	0.108032	0.246101	0.439	| | |	0.016
5	-2.091	-2.144	0.094707	-2.740	-1.548	0.053010	0.248595	0.213	| | |	0.003
6	-1.586	-1.659	0.077776	-2.244	-1.074	0.073607	0.254401	0.289	| | |	0.004
7	-1.992	-1.498	0.073049	-2.080	-.915694	-.494701	0.255799	-1.934	| ***| |	0.153
8	-1.153	-1.304	0.068209	-1.883	-.724508	0.151243	0.257131	0.588	| |* |	0.012
9	-.847298	-.980911	0.062688	-1.558	-.404279	0.133613	0.258533	0.517	| |* |	0.008
10	-.489548	-.851707	0.061535	-1.428	-.275628	0.362158	0.258810	1.399	| |** |	0.055
11	-.322773	-.670820	0.061041	-1.247	-.094975	0.348047	0.258927	1.344	| |** |	0.050
12	-.281851	-.496394	0.061826	-1.073	0.079823	0.214543	0.258740	0.829	| |* |	0.020
13	-.040005	-.302588	0.064091	-.879906	0.274731	0.262582	0.258189	1.017	| |** |	0.032
14	0.040005	-.076480	0.068392	-.655990	0.503031	0.116485	0.257003	0.453	| | |	0.007
15	0.241162	0.117327	0.073274	-.464834	0.699488	0.123835	0.255734	0.484	| | |	0.010
16	0.405465	0.311134	0.079045	-.274378	0.896646	0.094331	0.254010	0.371	| | |	0.007
17	0.426343	0.537242	0.086665	-.053050	1.128	-.110899	0.251512	-0.441	| | |	0.012
18	0.532217	0.731048	0.093788	0.135930	1.326	-.198831	0.248944	-0.799	| *| |	0.045
19	0.994623	1.119	0.109222	0.511938	1.725	-.124039	0.242569	-0.511	| *| |	0.027
20	1.099	1.539	0.127163	0.916490	2.161	-.439964	0.233663	-1.883	| ***| |	0.525
21	.	3.347	0.210958	2.631	4.064	.	.	.		.

SUM OF RESIDUALS -2.10665E-14
SUM OF SQUARED RESIDUALS 1.203074

DURBIN-WATSON D 1.101
1ST ORDER AUTOCORRELATION 0.429

APPENDIX C

Random Coefficient Model Calculations

I. COTCOSI Data.

A. Assuming that the percent of total cost for any contract is a function of time such that the slope parameter is distributed with mean B and var (wi) where i indicates some contract, the population parameters can be estimated using the regression model:

$$y_{ij} = B\ X_{ij} + W_{ij} \qquad \begin{array}{l} i = 1,2, \text{---}N \\ j = 1,2, \text{---}T \end{array}$$

where

$$W_{ij} = U_{ij} + V_i\ X_{ij}$$

B. If we let var (v_i) equal d^2 and the expected value equal zero then

$$\mathrm{var}(W_{ij}) = \sigma_2^{\,2} + d^2 X_{ij}{}^3. \quad \text{Thus we want}$$

to find B, d^2, and $\sigma_i^{\,2}$. This model is called the random coefficient regression model (RCR). Swamy suggested using generalized least squares

$$B = [\Sigma X_i{}' (\sigma_i^{\,2}\ I + d^2\ X_i\ X')^{-1}\ X]\ [\Sigma\ X_i{}'\ (\sigma_i{}^1\ I + d^2\ X_i\ X_i{}^1) y_i]$$

$$= \sum_{(i=1)}^{N} W_i\, B_i$$

D. For the five contracts used in the COTCOSI Study we get:

Ni	#						PROB > F	R^2
46	175	$\hat{y}_1$	=	-4.183 (.1102)	+12.889 (.3129)	TIME	.0001	.9741
28	200	$\hat{y}_2$	=	-4.544 (.1019)	+11.900 (.2759)	TIME	.0001	.9857
49	081	$\hat{y}_3$	=	- 2.95 (.0625)	+ 7.50 (.1556)	TIME	.0001	.9797
57	123	$\hat{y}_4$	=	-4.401 (.0512)	+ 9.47 (.1152)	TIME	.0001	.9797
19	0087	$\hat{Y}_5$	=	-3.113	+6.460	TIME	.0001	.9569

Note: The numbers in parenthesis are standard errors.

$$\hat{\sigma}_1^2 = 4.344012 \div 46 = .094435$$
$$\hat{\sigma}_2^2 = 1.775739 \div 28 = .0634193$$
$$\hat{\sigma}_3^2 = .985916 \div 49 = .0201207$$
$$\hat{\sigma}_4^2 = 1.125299 \div 57 = .0197421$$
$$\hat{\sigma}_5^2 = 1.203074 \div 19 = .0633197$$

where B_i is the regression coefficient using OLS.

C. For estimates of the parameters d^2 and $\sigma^2 i$,

we have

$$\sigma_i^2 = 1/T[\hat{U}_i{}' \hat{U}_i]$$

and

$$d^2 = 1/N \sum \hat{B}_i{}^2 - (1/N \sum \hat{B}_i)^2 = Var(\hat{b}_i)$$

$$\Sigma B_i = 12.888788 + 11.900510 + 7.499920 + 9.469604 + 6.460224$$
$$= 48.219046$$

$$\hat{B}_i = 9.6438092 \quad \text{and} \quad B_i^2 = 93.003056$$

$$\Sigma \hat{B}_i^2 = 166.12086 + 141.62214 + 56.2488 + 89.6734 + 41.734494$$
$$= 495.39969$$

$$\Sigma \hat{B}_i^2 \div 5 = 99.079938$$

$$d^2 = 99.079938 - 93.003056 = 6.0963241$$

Because

$$wi = \frac{1/(d^2 + \sigma_i^2/X_i' X_i)}{\sum_{j=1}^{N} 1/(d^2 + \sigma_j^2/ X_j' X_j)}$$

where $\sigma_i^2 / (X_i' X_i) = \text{var}(\hat{B}_i)$

and
$$(X_1' X_1) = .098728 \div .0979271 = 1.0081789$$
$$(X_2' X_2) = .068298 \div .0761357 = .8970561$$
$$(X_3' X_3) = .020977 \div .0242132 = .8663447$$
$$(X_4' X_4) = .020460 \div .013248 = 1.54438$$
$$(X_5' X_5) = .070769 \div .1041831 = .6792755$$

$\sigma_1{}^2/X_1{}^1\ X_1 = .094435 - 1.0081789 = .0936689$

$\sigma_2{}^2/X_2{}^1\ X_2 = .0634193 \div .8970561 = .0706971$

$\sigma_3{}^2/X_3{}^1\ X_3 = .0201207 \div .8663447 = .0232248$

$\sigma_4{}^2/X_4{}^1\ X_4 = .0197421 - 1.54438 = .0127832$

$\sigma_5{}^2/X_5{}^1\ X_5 = .0633197 \div .6792755 = .0932165$

$$\Sigma[d^2 + \sigma_j{}^2/(X_j{}^1\ X_j)]^{-1} = (.093689 + 6.0963241)^{-1}$$

$$+ (.0706971 + 6.0963241)^{-1}$$

$$+ (.0232248 + 6.0963241)^{-1}$$

$$+ (.0127832 + 6.0963241)^{-1}$$

$$+ (.0932165 + 6.0963241)^{-1}$$

$$= .8123676$$

we get

$$w_1 = (1/(6.0963241 + .0936689))/.8123676 = .1988645$$

$$w_2 = (1/(6.0963241 + .0906971))/.8123676 = .1996053$$

$$w_3 = (1/(6.0963241 + .0232248))/.8123676 = .2011537$$

$$w_4 = (1/(6.0963241 + .0127832))/.8123676 = .2014975$$

$$w_5 = (1/(6.0963241 + .0932165))/.8123676 = .198879$$

Thus,

$$B = 2.5631224 + 2.3754049 + 1.5086367 + 1.9081015 + 1.2913206$$

$$= 9.6465861$$

Our equation then is

$$\ln (cost/1 - cost) = -3.884 + 9.647 \quad TIME$$

$$\frac{COST}{1-COST} \quad -3.884 + 9.647 \quad TIME$$

$$COST = \frac{1}{1 + e^{3.884 - 9.647 \quad TIME}}$$

E. The Random Coefficient Model applied to equations corrected for autocorrelation gives

		σ^2
Y_1	$= -4.792 + 10.413\,X$	.0072
Y_2	$= 20.6 + 6.163\,X$	.017
Y_3	$= -4.516 + 11.924\,X$	.043
Y_4	$= -2.18 + 6.195\,X$	.004
Y_5	$= -3.431 + 5.837\,X$	.048

$\sum B_i = 40.532$ $\quad \bar{\hat{B}}_i = 8.106$ $\quad \bar{\hat{B}}_i^2 = 65.713$

$\sum \hat{B}_i^2 = 361.04$ $\quad \bar{\hat{B}}^2 = 72.2$

$d^2 = 72.2 - 65.713 = 6.487 \div 16. = .405$

$$X_1'X_1 = .0072 - 1.69 = .0011$$

$$X_2'X_2 = .017 - 9.36 = .00088$$

$$X_3'X_3 = .043 - .336 = .1279$$

$$X_4'X_4 = .004 - .409 = .0098$$

$$X_5'X_5 = .048 - .25 = .192$$

$$\begin{aligned}\sum\left[d^2 + \sigma_j^2/(X_j' X_j)\right]^{-1} &= ((.405 + (.0072))^{-1} \\ &+ ((.405 + (.017))^{-1} \\ &+ ((.405 + (.043))^{-1} \\ &+ ((.405 + (.004))^{-1} \\ &+ ((.405 + (.048))^{-1} \\ &= 11.680\end{aligned}$$

$W_1 = .207$

$W_2 = .203$

$W_3 = .191$

$W_4 = .209$

$W_5 = .189$

$$\hat{B} = 10.413\ (.207) + 6.163\ (.203) + 11.924\ (.191) + 6.195\ (.209 + 5.837\ (.189)$$

$$= 8.0807$$

$$\hat{\alpha} = .346871 - 8.0807 * .3666734$$

$$= -2.6161067$$

The equation then corrected for autocorrelation is

$$\ln\left[\frac{\text{cost}}{1-\text{cost}}\right] = -2.6161067 + 8.0898 \quad \text{TIME}$$

$$\text{cost} = \frac{1}{1 + \exp 2.616 - 8.081} \quad \text{TIME}$$

APPENDIX D

Pooled Regression Output

DEP VARIABLE: DEPY

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	1	449.129	449.129	1057.135	0.0001
ERROR	197	83.696356	0.424855		
C TOTAL	198	532.825			

ROOT MSE	0.651809	R-SQUARE	0.8429
DEP MEAN	-0.346871	ADJ R-SQ	0.8421
C.V.	-187.911		

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|
INTERCEP	1	-3.729411	0.113834	-32.762	0.0001
TIME	1	9.224940	0.283725	32.514	0.0001

OBS	ACTUAL	PREDICT VALUE	STD ERR PREDICT	LOWER95% PREDICT	UPPER95% PREDICT	RESIDUAL	STD ERR RESIDUAL	STUDENT RESIDUAL	-2-1-0 1 2	COOK'S D
1	.	-3.729	0.113834	-5.034	-2.425	.	.	.		.
2	.	-3.729	0.113834	-5.034	-2.425	.	.	.		.
3	.	-3.729	0.113834	-5.034	-2.425	.	.	.		.
4	.	-3.729	0.113834	-5.034	-2.425	.	.	.		.
5	.	-3.729	0.113834	-5.034	-2.425	.	.	.		.
6	-4.595	-3.314	0.102297	-4.615	-2.013	-1.281	0.643731	-1.990	***	0.050
7	-4.595	-3.360	0.103564	-4.662	-2.059	-1.235	0.643529	-1.919	***	0.048
8	-4.595	-3.637	0.111247	-4.941	-2.333	-.957958	0.642245	-1.492	**	0.033
9	-4.411	-3.176	0.098518	-4.476	-1.876	-1.235	0.644320	-1.917	***	0.043
10	-3.892	-2.899	0.091088	-4.197	-1.601	-.992654	0.645413	-1.538	***	0.024
11	-3.892	-3.084	0.096022	-4.383	-1.784	-.808155	0.644697	-1.254	**	0.017
12	-3.892	-3.360	0.103564	-4.662	-2.059	-.531407	0.643529	-0.826	*	0.009
13	-3.892	-3.176	0.098518	-4.476	-1.876	-.715985	0.644320	-1.111	**	0.014
14	-3.476	-2.853	0.089869	-4.151	-1.555	-.623057	0.645584	-0.965	*	0.009
15	-3.317	-2.669	0.085052	-3.965	-1.372	-.648237	0.646236	-1.003	**	0.009
16	-3.178	-2.991	0.093545	-4.290	-1.693	-.186638	0.645061	-0.289		0.001
17	-3.178	-2.622	0.083864	-3.918	-1.326	-.555635	0.646391	-0.860	*	0.006
18	-3.178	-3.268	0.101033	-4.569	-1.967	0.090111	0.643931	0.140		0.000
19	-3.055	-2.392	0.078043	-3.686	-1.097	-.663254	0.647120	-1.025	**	0.008
20	-2.944	-2.899	0.091088	-4.197	-1.601	-.045272	0.645413	-0.070		0.000
21	-2.944	-2.438	0.079190	-3.733	-1.143	-.506519	0.646580	-0.783	*	0.005
22	-2.769	-2.161	0.072448	-3.455	-.867823	-.608234	0.647770	-0.939	*	0.006
23	-2.752	-2.115	0.071361	-3.408	-.821934	-.636400	0.647891	-0.982	*	0.006
24	-2.752	-2.761	0.087447	-4.058	-1.464	0.009257	0.645916	0.014		0.000
25	-2.752	-2.807	0.088655	-4.104	-1.510	0.055382	0.645751	0.086		0.000
26	-2.587	-2.622	0.083864	-3.918	-1.326	0.035729	0.646391	0.055		0.000
27	-2.587	-2.060	0.070073	-3.353	-.766858	-.526992	0.648031	-0.813	*	0.004
28	-2.442	-1.884	0.066115	-3.176	-.592395	-.557924	0.648447	-0.860	*	0.004
29	-2.415	-2.484	0.080347	-3.779	-1.189	0.068566	0.646838	0.106		0.000
30	-2.376	-1.700	0.062183	-2.991	-.408656	-.676348	0.648836	-1.042	**	0.005
31	-2.314	-1.654	.061243	-2.945	-.362786	-.659835	0.648925	-1.017	**	0.005
32	-2.314	-1.931	.067137	-3.223	-.638315	-.383087	0.648342	-0.591	*	0.002

OBS	ACTUAL	PREDICT VALUE	STD ERR PREDICT	LOWER95% PREDICT	UPPER95% PREDICT	RESIDUAL	STD ERR RESIDUAL	STUDENT RESIDUAL	-2-1-0 1 2	COOK'S D
33	-2.197	-1.562	0.059419	-2.852	-.270788	-.635674	0.649075	-0.979	*|	0.004
34	-2.197	-2.300	0.075775	-3.594	-1.005	0.102321	0.647389	0.158	|	0.000
35	-2.197	-2.576	0.082684	-3.872	-1.281	0.379669	0.646543	0.586	|*	0.003
36	-2.143	-1.506	0.058364	-2.797	-.215625	-.636663	0.649190	-0.981	*|	0.004
37	-2.091	-1.423	0.056840	-2.713	-.132866	-.667565	0.649326	-1.028	**|	0.004
38	-2.091	-1.377	0.056026	-2.667	-.086879	-.713689	0.649396	-1.099	**|	0.004
39	-2.091	-1.700	0.062183	-2.991	-.408656	-.390817	0.648836	-0.602	*|	0.002
40	-2.091	-2.346	0.076904	-3.640	-1.051	0.254929	0.647236	0.394	|	0.001
41	-1.992	-2.161	0.072448	-3.455	-.867823	0.168741	0.647770	0.260	|	0.000
42	-1.992	-1.423	0.056840	-2.713	-.132866	-.569254	0.649326	-0.877	*|	0.003
43	-1.901	-2.161	0.072448	-3.455	-.867823	0.260213	0.647770	0.402	|	0.001
44	-1.901	-1.995	0.068592	-3.288	-.702592	0.094164	0.648190	0.145	|	0.000
45	-1.815	-1.977	0.068174	-3.269	-.684228	0.161383	0.648234	0.249	|	0.000
46	-1.774	-1.285	0.054471	-2.575	0.005111	-.489566	0.649529	-0.754	*|	0.002
47	-1.735	-1.239	0.053733	-2.528	0.051115	-.495924	0.649590	-0.763	*|	0.002
48	-1.666	-1.146	0.052342	-2.436	0.143142	-.519259	0.649704	-0.799	*|	0.002
49	-1.658	-1.884	0.066115	-3.176	-.592395	0.226195	0.648447	0.349	|	0.001
50	-1.621	-1.1[illegible]	0.051691	-2.398	0.109165	-.521183	0.649736	-0.802	*|	0.002
51	-1.586	-2.0[illegible]	0.069223	-3.315	-.730136	0.437178	0.648122	0.675	|*	0.003
52	-1.586	-1.654	0.061243	-2.945	-.362706	0.068173	0.648925	0.105	|	0.000
53	-1.516	-1.054	0.051070	-2.344	0.235193	-.462169	0.649805	-0.711	*|	0.002
54	-1.516	-1.377	0.056026	-2.667	-.086879	-.139296	0.649396	-0.215	|	0.000
55	-1.450	-1.838	0.065108	-3.130	-.546469	0.388288	0.648549	0.599	|*	0.002
56	-1.386	-.915885	0.049408	-2.205	0.373316	-.470498	0.649933	-0.724	*|	0.002
57	-1.386	-1.884	0.066115	-3.176	-.592395	0.498129	0.648447	0.768	|*	0.003
58	-1.386	-1.746	0.063141	-3.037	-.454600	0.359755	0.648743	0.555	|*	0.001
59	-1.325	-1.838	0.065108	-3.130	-.546469	0.513373	0.648549	0.792	|*	0.003
60	-1.325	-1.700	0.062183	-2.991	-.408656	0.374999	0.648836	0.578	|*	0.002
61	-1.266	-.777430	0.048066	-2.066	0.511492	-.488236	0.650034	-0.751	*|	0.002
62	-1.266	-1.608	0.060321	-2.899	-.316750	0.342009	0.649012	0.527	|*	0.001
63	-1.153	-.685181	0.047363	-1.974	0.603640	-.467498	0.650086	-0.719	*|	0.001
64	-1.153	-1.193	0.053023	-2.482	0.097126	0.039673	0.649648	0.061	|	0.000
65	-1.153	-1.146	0.052342	-2.436	0.143142	-.006251	0.649704	-0.010	|	0.000
66	-1.099	-1.700	0.062183	-2.991	-.408656	0.601312	0.648836	0.927	|*	0.004
67	-1.099	-1.515	0.058538	-2.806	-.224820	0.416813	0.649175	0.642	|*	0.002
68	-1.072	-.574482	0.046733	-1.863	0.714250	-.497639	0.650131	-0.765	*|	0.002
69	-1.046	-1.423	0.056840	-2.713	-.132866	0.377200	0.649326	0.581	|*	0.001
70	-.944462	-1.377	0.056026	-2.667	-.086879	0.432590	0.649396	0.666	|*	0.002
71	-.919793	-.408433	0.046244	-1.697	0.880231	-.511360	0.650166	-0.787	*|	0.002
72	-.895384	-1.285	0.054471	-2.575	0.005111	0.389418	0.649529	0.600	|*	0.001
73	-.847298	-1.515	0.058538	-2.806	-.224820	0.668128	0.649175	1.029	|**	0.004
74	-.847298	-.685181	0.047363	-1.974	0.603640	-.162117	0.650086	-0.249	|	0.000
75	-.753772	-.316183	0.046215	-1.605	0.972476	-.437588	0.650168	-0.673	*|	0.001
76	-.753772	-.961929	0.049928	-2.251	0.327269	0.208157	0.649894	0.320	|	0.000
77	-.753772	-1.239	0.053733	-2.528	0.051115	0.484986	0.649590	0.746	|*	0.002
78	-.708185	-.270059	0.046266	-1.559	1.019	-.438126	0.650165	-0.674	*|	0.001
79	-.663294	-1.165	0.052611	-2.454	0.124735	0.501584	0.649682	0.772	|*	0.002
80	-.619039	-1.146	0.052342	-2.436	0.143142	0.527389	0.649704	0.812	|*	0.002
81	-.597133	-.131685	0.046677	-1.420	1.157	-.465448	0.650135	-0.716	*|	0.001
82	-.553728	-.085560	0.046899	-1.374	1.203	-.468168	0.650119	-0.720	*|	0.001
83	-.532217	-1.349	0.055549	-2.639	-.059285	0.817160	0.649437	1.258	|**	0.006
84	-.532217	-1.054	0.051070	-2.344	0.235193	0.521962	0.649805	0.803	|*	0.002
85	-.489548	-1.008	[illegible]50482	-2.297	0.281228	0.518506	0.649851	0.798	|*	0.002
86	-.4[illegible]48	-.500682	0.046447	-1.789	0.788010	0.011134	0.6501[illegible]	0.017	|	0.000

OBS	ACTUAL	PREDICT VALUE	STD ERR PREDICT	LOWER95% PREDICT	UPPER95% PREDICT	RESIDUAL	STD ERR RESIDUAL	STUDENT RESIDUAL	-2-1-0 1 2	COOK'S D
87	-.447312	0.006689	0.047468	-1.282	1.296	-.454002	0.650078	-0.698	*:	0.001
88	-.447312	-.215805	0.049400	-2.205	0.373316	0.468492	0.649933	0.721	:*	0.002
89	-.426343	-.851230	0.048740	-2.140	0.437791	0.424887	0.649984	0.654	:*	0.001
90	-.405465	0.052814	0.047813	-1.236	1.342	-.458279	0.650053	-0.705	*:	0.001
91	-.405465	-.869680	0.048923	-2.159	0.419368	0.464215	0.649970	0.714	:*	0.001
92	-.322773	-.685181	0.047363	-1.974	0.603640	0.362408	0.650086	0.557	:*	0.001
93	-.322773	-.242384	0.046317	-1.531	1.046	-.080389	0.650161	-0.124	:	0.000
94	-.281851	-1.239	0.053733	-2.528	0.051115	0.956826	0.649590	1.473	:**	0.007
95	-.281851	-.592932	0.046821	-1.882	0.695813	0.311081	0.650125	0.478	:	0.001
96	-.281851	0.006689	0.047468	-1.282	1.296	-.288541	0.650078	-0.444	:	0.001
97	-.241162	0.145064	0.048620	-1.144	1.434	-.386226	0.649993	-0.594	*:	0.001
98	-.241162	-.500682	0.046447	-1.789	0.788010	0.259520	0.650152	0.399	:	0.000
99	-.200671	0.237313	0.049576	-1.052	1.526	-.437984	0.649921	-0.674	*:	0.001
100	-.200671	-1.146	0.052342	-2.436	0.143142	0.945757	0.649704	1.456	:**	0.007
101	-.200671	-.675956	0.047301	-1.965	0.612857	0.475285	0.650090	0.731	:*	0.001
102	-.200671	-.408433	0.046244	-1.697	0.880231	0.207762	0.650166	0.320	:	0.000
103	-.160343	0.283438	0.050108	-1.006	1.573	-.443780	0.649880	-0.683	*:	0.001
104	-.160343	-.316183	0.046215	-1.605	0.972476	0.155841	0.650168	0.240	:	0.000
105	-.140229	-.270059	0.046266	-1.559	1.019	0.129829	0.650165	0.200	:	0.000
106	-.124159	-.242384	0.046317	-1.531	1.046	0.118225	0.650161	0.182	:	0.000
107	-.080043	-.223934	0.046360	-1.513	1.065	0.143891	0.650158	0.221	:	0.000
108	-.040005	0.329562	0.050673	-.959749	1.619	-.369568	0.649836	-0.569	*:	0.001
109	-.040005	-.131685	0.046677	-1.420	1.157	0.091679	0.650135	0.141	:	0.000
110	-.040005	0.283438	0.050108	-1.006	1.573	-.323443	0.649880	-0.498	:	0.001
111	0	-1.054	0.051070	-2.344	0.235193	1.054	0.649805	1.622	:***	0.008
112	0	-.408433	0.046244	-1.697	0.880231	0.408433	0.650166	0.628	:*	0.001
113	0.040005	0.514061	0.053255	-.775655	1.804	-.474056	0.649630	-0.730	*:	0.002
114	0.040005	-.085560	0.046899	-1.374	1.203	0.125565	0.650119	0.193	:	0.000
115	0.040005	0.606311	0.054721	-.683644	1.896	-.566305	0.649508	-0.872	*:	0.003
116	0.044007	-1.008	0.050482	-2.297	0.281228	1.052	0.649851	1.619	:***	0.008
117	0.060018	-.823555	0.048476	-2.113	0.465427	0.883573	0.650004	1.359	:**	0.005
118	0.080043	0.006689	0.047468	-1.282	1.296	0.073353	0.650078	0.113	:	0.000
119	0.120144	0.606311	0.054721	-.683644	1.896	-.486166	0.649508	-0.749	*:	0.002
120	0.120144	0.052814	0.047813	-1.236	1.342	0.067330	0.650053	0.104	:	0.000
121	0.160343	0.145064	0.048620	-1.144	1.434	0.015279	0.649993	0.024	:	0.000
122	0.200671	0.698560	0.056292	-.591657	1.989	-.497889	0.649373	-0.767	*:	0.002
123	0.200671	0.218863	0.049373	-1.070	1.508	-.018192	0.649936	-0.028	:	0.000
124	0.241162	0.744685	0.057114	-.545673	2.035	-.503523	0.649302	-0.775	*:	0.002
125	0.241162	0.283438	0.050108	-1.006	1.573	-.042276	0.649880	-0.065	:	0.000
126	0.241162	0.883059	0.059715	-.407757	2.174	-.641897	0.649068	-0.989	*:	0.004
127	0.281851	-.223934	0.046360	-1.513	1.065	0.505785	0.650158	0.778	:*	0.002
128	0.281851	0.375687	0.051272	-.913716	1.665	-.093836	0.649789	-0.144	:	0.000
129	0.322773	0.790809	0.057960	-.499695	2.081	-.468036	0.649227	-0.721	*:	0.002
130	0.363965	0.929183	0.060624	-.361797	2.220	-.565218	0.648983	-0.871	*:	0.003
131	0.363965	-.639056	0.047071	-1.928	0.649724	1.003	0.650107	1.543	:***	0.006
132	0.363965	0.514061	0.053255	-.775655	1.804	-.150096	0.649630	-0.231	:	0.000
133	0.384674	-.592932	0.046821	-1.882	0.695813	0.977606	0.650125	1.504	:***	0.006
134	0.405465	-.085560	0.046899	-1.374	1.203	0.491025	0.650119	0.755	:*	0.001
135	0.405465	1.160	0.065446	-.132088	2.452	-.754342	0.648515	-1.163	**:	0.007
136	0.426343	1.483	0.072810	0.189253	2.776	-1.056	0.647729	-1.631	***:	[illegible]317
137	0.447312	0.560186	0.0[illegible]974	-.729646	1.850	-.112874	0.649570	-0.174	:	0.000
138	0.489548	0.975308	0.[illegible]61552	-.315843	2.266	-.485760	0.648896	-0.749	*:	0.003
139	0.4[illegible]48	0.098939	[illegible]48197	-1.199	1.388	0.390609	0.650[illegible]	0.601	:*	0.001
140	0.5[illegible]17	-.540807	0.046613	-1.836	0.741908	1.079	0.6501[illegible]	1.660	:***	0.007

OBS	ACTUAL	PREDICT VALUE	STD ERR PREDICT	LOWER95% PREDICT	UPPER95% PREDICT	RESIDUAL	STD ERR RESIDUAL	STUDENT RESIDUAL	-2-1-0 1 2	COOK'S D
141	0.532217	0.698560	0.056292	-.591657	1.989	-.1[illegible]43	0.649373	-0.256	: :	0.000
142	0.532217	1.759	0.079572	0.464453	3.054	-1.227	0.646933	-1.897	***:	0.027
143	0.575364	1.068	0.063462	-.223953	2.359	-.492193	0.648712	-0.759	*:	0.003
144	0.619039	1.160	0.065440	-.132088	2.452	-.540768	0.648515	-0.834	*:	0.004
145	0.663294	1.206	0.066452	-.086164	2.498	-.542637	0.648413	-0.837	*:	0.004
146	0.663294	1.344	0.069573	0.051571	2.637	-.681012	0.648085	-1.051	**:	0.006
147	0.663294	0.836934	0.058827	-.453723	2.128	-.173640	0.649149	-0.267	:	0.000
148	0.708185	-.362308	0.046208	-1.651	0.926350	1.070	0.650169	1.646	:***	0.007
149	0.708185	0.375687	0.051272	-.913716	1.665	0.332498	0.649789	0.512	:*	0.001
150	0.753772	1.390	0.070640	0.097471	2.683	-.636659	0.647970	-0.983	*:	0.006
151	0.753772	0.975308	0.061552	-.315843	2.266	-.221536	0.648896	-0.341	:	0.001
152	0.758371	1.021	0.062498	-.269895	2.313	-.263062	0.648806	-0.405	:	0.001
153	0.800119	1.529	0.073912	0.235134	2.822	-.728685	0.647605	-1.125	**:	0.008
154	0.800119	-.316183	0.046215	-1.605	0.972476	1.116	0.650168	1.717	:***	0.007
155	0.847298	1.621	0.076147	0.326888	2.915	-.773756	0.647346	-1.195	**:	0.010
156	0.847298	-.223934	0.046360	-1.513	1.065	1.071	0.650158	1.648	:***	0.007
157	0.847298	1.160	0.065440	-.132088	2.452	-.312509	0.648515	-0.482	:	0.001
158	0.895384	-.177809	0.046497	-1.467	1.111	1.073	0.650148	1.651	:***	0.007
159	0.994623	1.667	0.077279	0.372743	2.962	-.672[illegible]56	0.647211	-1.039	**:	0.010
160	0.994623	-.131685	0.046677	-1.420	1.157	1.126	0.650135	1.732	:***	0.008
161	0.994623	0.698560	0.056292	-.591657	1.989	0.296063	0.649373	0.456	:	0.001
162	0.994623	1.298	0.068519	0.005666	2.591	-.303559	0.648197	-0.468	:	0.001
163	0.994623	2.313	0.093953	1.014	3.612	-1.318	0.645002	-2.044	****:	0.044
164	1.046	-.039435	0.047163	-1.328	1.249	1.085	0.650100	1.670	:***	0.007
165	1.099	1.806	0.080731	0.510298	3.101	-.706941	0.646790	-1.093	**:	0.009
166	1.099	2.913	0.110384	1.609	4.216	-1.814	0.642394	-2.824	*****:	0.118
167	1.153	0.006689	0.047468	-1.282	1.296	1.146	0.650078	1.763	:***	0.008
168	1.208	1.898	0.083073	0.601972	3.194	-.689491	0.646493	-1.067	**:	0.009
169	1.208	0.071264	0.047962	-1.218	1.360	1.137	0.650042	1.749	:***	0.008
170	1.208	0.744685	0.057114	-.545673	2.035	0.463627	0.649302	0.714	:*	0.002
171	1.225	0.191183	0.049080	-1.098	1.480	1.034	0.649958	1.591	:***	0.007
172	1.266	0.246538	0.049679	-1.043	1.536	1.019	0.649913	1.568	:***	0.007
173	1.266	0.790809	0.057960	-.499695	2.081	0.474857	0.649227	0.731	:*	0.002
174	1.325	0.329562	0.050673	-.959749	1.619	0.995363	0.649836	1.532	:***	0.007
175	1.325	1.068	0.063462	-.223953	2.359	0.257368	0.648712	0.397	:	0.001
176	1.325	1.390	0.070640	0.097471	2.683	-.065505	0.647970	-0.101	:	0.000
177	1.355	1.990	0.085446	0.693621	3.286	-.634719	0.646184	-0.982	*:	0.008
178	1.386	0.421812	0.051903	-.867690	1.711	0.964483	0.649739	1.484	:**	0.007
179	1.456	2.036	0.086643	0.739437	3.333	-.586166	0.646025	-0.907	*:	0.007
180	1.483	2.082	0.087846	0.785247	3.379	-.599469	0.645862	-0.928	*:	0.008
181	1.516	0.514061	0.053255	-.775655	1.804	1.002	0.64963[illegible]	1.543	:***	0.008
182	1.516	1.344	0.069573	0.051571	2.637	0.172042	0.648085	0.265	:	0.000
183	1.516	1.667	0.077279	0.372743	2.962	-.150831	0.647211	-0.233	:	0.000
184	1.586	2.175	0.090271	0.876849	3.472	-.588923	0.645527	-0.912	*:	0.[illegible]08
185	1.586	0.652435	0.055494	-.637648	1.943	0.933192	0.649442	1.437	:**	0.[illegible]08
186	1.658	2.175	0.090271	0.876849	3.472	-.516322	0.645527	-0.800	*:	0.006
187	1.658	1.806	0.080731	0.510298	3.101	-.147325	0.646790	-0.228	:	0.000
188	1.735	1.621	0.076147	0.326888	2.915	0.113547	0.647346	0.175	:	0.000
189	1.782	2.267	0.092720	0.968427	3.565	-.484343	0.645180	-0.751	*:	[illegible]006
190	1.815	2.451	0.097681	1.152	3.751	-.636009	0.644448	-0.987	*:	[illegible]011
191	1.815	1.990	0.[illegible]85446	0.693621	3.286	-.174762	0.64618[illegible]	-0.270	:	[illegible]001
192	[illegible]91	0.698560	0.[illegible]56292	-.591657	1.989	1.202	0.6493[illegible]	1.852	:***	[illegible]013
193	1.[illegible]01	2.359	0.095190	1.068	3.658	-.458090	0.6448[illegible]	-0.710	*:	[illegible]005
194	1.992	0.790809	0.057960	-.499695	2.081	1.202	0.649227	1.851	:***	[illegible]014

OBS	ACTUAL	PREDICT VALUE	STD ERR PREDICT	LOWER95% PREDICT	UPPER95% PREDICT	RESIDUAL	STD ERR RESIDUAL	STUDENT RESIDUAL	-2-1-0 1 2	COOK'S D
195	2.091	0.883059	0.059715	-.407757	2.174	1.208	0.649068	1.861	:***	0.015
196	2.197	0.975308	0.061552	-.315843	2.266	1.222	0.648896	1.883	:***	0.016
197	2.197	2.544	0.100189	1.243	3.844	-.346323	0.644063	-0.538	*:	0.003
198	2.314	2.820	0.107814	1.517	4.123	-.506661	0.642830	-0.788	*:	0.009
199	2.314	1.068	0.063462	-.223953	2.359	1.246	0.648712	1.921	:***	0.018
200	2.442	1.160	0.065440	-.132088	2.452	1.283	0.648515	1.978	:***	0.020
201	2.442	1.252	0.067478	-.040246	2.544	1.190	0.648306	1.836	:***	0.018
202	2.587	1.344	0.069573	0.051571	2.637	1.242	0.648085	1.917	:***	0.021
203	2.944	1.898	0.083073	0.601972	3.194	1.047	0.646493	1.619	:***	0.022
204	3.317	2.082	0.087846	0.785247	3.379	1.234	0.645862	1.911	:***	0.034
205	.	5.496	0.185536	4.159	6.832	.	.	.		.
206	.	5.496	0.185536	4.159	6.832	.	.	.		.
207	.	5.496	0.185536	4.159	6.832	.	.	.		.
208	.	5.496	0.185536	4.159	6.832	.	.	.		.
209	.	5.496	0.185536	4.159	6.832	.	.	.		.

SUM OF RESIDUALS -2.45670E-12
SUM OF SQUARED RESIDUALS 83.69636

DURBIN-WATSON D 1.688
1ST ORDER AUTOCORRELATION 0.157

0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0

NOTE: 5 OBS HAD MISSING VALUES 439 OBS HIDDEN

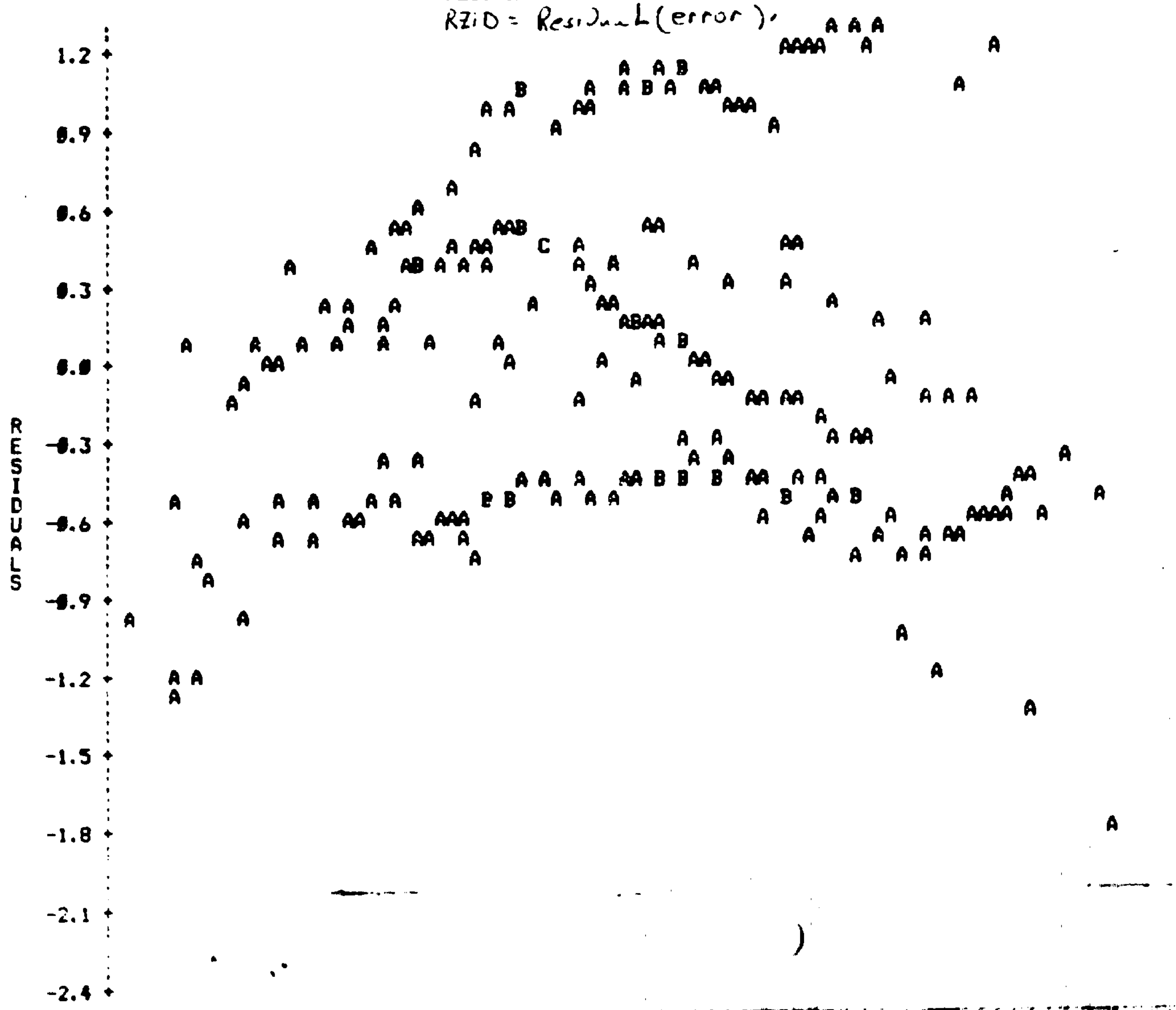
APPENDIX D (Continued)

Graph

FMS PAYMENT SCHEDULE FUNCTION 9:10 WEDNESDAY, NOVEMBER 28, 1984 8

PLOT OF RZID*TIME LEGEND: A = 1 OBS, B = 2 OBS, ETC.

RZID = Residual (error),



APPENDIX E
Summary of AR 37-60 Equations

Method				R^2
Cramers	CM 83-28	$y_1 =$	$103.4(1 - \exp - .000003411989X_1^3)$	-
OLS	Payment Schedule	$y =$	$1/1 + \exp(3.957439 - 9.257841X)$	.94
OLS	Liability Schedule	$y =$	$1/1 + \exp(5.744213 - 9.694010X)$	.97
OLS	Corrected Liability Schedule	$y =$	$1/1 + \exp(10.757 - 14.94798X)$	.94
ML	Liability Schedule	$y_1 =$	$112.258(1 - \exp - .000196378X_1^2)$	.86
ML	Liability Schedule	$y_1 =$	$91.869(1 - \exp - .00000443551X_1^3)$	.88

$X_1 = 100 * X$

$Y_1 = 100 * X$

GLOSSARY

Accessorial costs - Charges assessed for certain expenses for issues, sales, and transfer of materiel. The charges are for packing, crating, handling, and transportation, port loading and unloading, positioning costs, and other expenses incident to the FMS sale but not included in the standard price or contract cost.

Administrative charges - Charges for Quality Assurance and Inspection, contract administration, audits and other general management and administrative expenses.

Aggregation Bias - Bias in parameter estimate due to combining micro data.

Asset Use Charge - Charges assessed for the use of Government owned property and plant equipment.

Autocorrelation - The disturbance term in the regression model is dependent on the value of the disturbance term in an earlier period.

Contractor holdback - Percent of progress payment withheld. Contractor payment plus holdback equals the progress payment.

Dependable Undertaking - A firm commitment made by a foreign Government or international organization to pay the full cost of and to ensure the US Government against any loss on a contract for new production or the performance of defense services.

Durbin Watson Statistic - Statistic used to indicate the degree of autocorrelation among the error terms.

F Test - Statistical test that uses the F distribution named after Sir R. A. Fisher.

First Differencing - Procedure that is used to adjust data so that first order correlation is eliminated.

FMS Case - A DD Form 1513 "United States Department of Defense Order and Acceptance," which has been accepted by a foreign country.

Logistic Curve - S-shaped curve that is often used in growth models.

Maximum Likelihood Method - Statistical prccedure that estimates population parameters which would give highest probability of generating the sample observed.

Ordinary Least Squares - Regression technique that fits a line to data points in order to show the relationship between a dependent variable and one or more independent variables.

Progress Payments - Payments to a contractor based upon his accomplishments to date.

Quasi differencing - Procedure that is used to eliminate autocorrelation from regression error terms.

Random Coefficient Model - Regression model that assumes the beta coefficients are random variables.

Standard Error - A statistic that indicates the spread due to sampling error about the parameter estimate.